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CHARACTERIZATION OF MATERIALS OVERLYING COAL SEAMS AS PLANT GROWTH MEDIA-EMRIA EMERY, UTAH SITE

FINAL REPORT

Colorado State University

DEPARTMENT OF AGRONOMY

Soil Survey and Interpretation Research Group

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FINAL REPORT

to

U.S. BUREAU OF LAND MANAGEMENT

U.S. DEPARTMENT OF INTERIOR

DENVER, COLORADO

Submitted by

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May 15, 1979

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INTRODUCTION

This report describes the results of a study conducted for the U.S. Bureau of Land Management to characterize selected soil and geologic overburden materials from the EMRIA EMERY, UTAH mined land reclamation study site.

The study reported herein is part of an overall study being made jointly by Geoscientific Systems and Consulting, Playa del Ray, California, the U.S. Bureau of Land Management and Colorado State University.

The objectives of this portion of the study were:

1. Laboratory characterization to describe the geochemical nature of selected soil and geologic overburden materials.
2. To conduct greenhouse growth studies and accompanying plant tissue analyses to determine the potential opportunities and/or constraints that overburden materials studied offer as plant growth media.

This report replaces preliminary reports dated June 28, 1978 and March 1, 1979 which were submitted to the U.S. Bureau of Land Management as progress reports.

THE REPORT

Part I of this report describes the procedures used as part of the laboratory and greenhouse characterization program.

Part II describes the procedure and rationale used for determining the kinds and combinations of chemical and physical characteristics of materials from Bore Holes 3, 4, 5 and 6, which affect suitability as plant growth media.

Part III describes the rationale and procedure used for evaluating the geochemical nature of the materials studied.

Part IV describes the results obtained from the greenhouse growth and plant tissue analyses portion of the study.

Part V includes the results of some additional laboratory analyses performed on samples submitted from Bore Holes 1 and 2.

Part VI describes the results of some additional greenhouse studies involving the use of native species other than western wheatgrass.

Part VII deals with the mineralogical studies which were conducted.

Part VIII is a general summary of the results of the work conducted.

PART I

PROCEDURES

Laboratory Procedures

Following are described the laboratory methods used to characterize the overburden material for those properties selected as a basis for determining plant growth suitability as for the geochemical and plant tissue analyses.

pH

Determined with a combination electrode pH meter on a saturated soil paste.

Extractable Phosphorus

Determined on a spectrophotometer from a sodium bicarbonate extract. The resultant value, reported in parts per million phosphorus (P), is an index of available phosphorus.

Exchangeable Sodium, Potassium, Calcium and Magnesium

Determined on a flame photometer from an ammonium acetate extract. The values are reported as parts per million Na, K, Ca, and Mg respectively.

Extractable Calcium and Magnesium

Determined by the versenate titration method from a water saturation extract. The results are reported as millequivalents per liter calcium (Ca) and magnesium (Mg).

Sand, Silt, and Clay

Determined by the hydrometer method. The results are reported as percent sand (%S), silt (%S) and clay (%C).

Exchangeable Sodium Percentage

Determined directly by:

$$ESP = \frac{\text{Exch. Na Meq/100 gm}}{\text{C.E.C. - Exch. Na Meq/100 gm}} \times 100$$

Cation Exchange Capacity

Determined by:

$$\text{CED meq/100 g} = \frac{\text{Exch. Na meq/liter x 10}}{\text{wt. of sample in grams}}$$

Extractable Zinc, Iron, Manganese, and Copper

Determined by using an extracting solution of diethylenetriamine pentaacetic acid (DTPA). The results are determined simultaneously using a spectrometer and are reported in parts per million.

Extractable Sodium and Potassium

Determined on a flame photometer from a saturation extract. The results are reported as millequivalents per liter sodium (Na) and magnesium (Mg).

Salinity (Electrical Conductivity)

Determined by a solu-bridge from a saturation extract. The results are reported as electrical conductivity in millimohs per centimeter (mmhos/cm).

Organic Matter

Determined by wet oxidation with spontaneous heat of reaction. The results are determined colormetrically and reported as percent organic matter (% O.M.).

Nitrate-Nitrogen

Determined on a spectrophotometer from a phenoldisulfonic acid extract. The result is reported in parts per million nitrate nitrogen.

Saturation Percentage

Determined by calculating ratio of air dry soil weight and weight of the soil at saturation point.

Extractable Boron, Lead, Arsenic, Selenium, Aluminum, Nickel, Molybdenium, Cadmium, Cobalt, Chromium, and Strontium.

Determined by using an extracting solution of ammonium bicarbonate and diethylenetriamine pentaacetic acid (DTPA). The results are determined using an inductively-coupled plasma optical emission spectrometer (ICP-OES).

Total Iron, Cadmium, Copper, Nickel, Zinc, Molybdenum, and Manganese

Determined by a hydrogen flouride acid digest on the ICP-OES.

Total Arsenic Selenium

Determined by a hydrogen flouride acid digest on the Atomic Adsorption spectrophometer.

Boron

Determined colormetrically from a hot water extract. The results are reported in parts per million hot water soluble boron.

Total Plant Calcium, Magnesium, Sodium, Phosphorus, Iron, Manganese, Copper Zinc, Cadmium and Nickel

Determined by a nitric perchloric acid digest on the ICP-OES. Results are reported in %CA, %MG, %Na, %P, and the remaining elements in parts per million.

Total Arsenic and Selenium

Determined by a nitric perchloric acid digest using hydride generation on the Atomic Adsorption Spectrophotometer.

Total Sulfur

Determined by the turbicmetric progress on a nitric perchloric acid digest. The results are reported in percent sulfur (%S).

Greenhouse Procedures

Materials received from Geoscientific Systems and Consulting had been ground to less than 2 mm size for greenhouse and geochemical analyses. Sample selection for the greenhouse study is described in Part IV of this report. Pot sizes ranged from 200 to 750 grams, depending on the amount of material available. Each sample was placed in a plastic bag in a plastic container and assigned a greenhouse identification number.

Fertilizer Treatment

Before planting, fertilizer was applied at a rate of 100 ppm nitrogen as reagent grade $Ca(NO_3)_2$; 80 ppm of phosphorus as reagent grade $Ca(H_2PO_4)_2$, and 80 ppm of potassium as KNO_3. This was done along with preplant watering. Before the fertilizer or water were added, 50 grams of soil was removed from each pot and saved. This material was placed back in the pot after planting. Additional N at a rate of 100 ppm was added to all pots 21 days after planting.

Planting

The pots were planted with 40 seeds of western wheatgrass (Agropyron smithii var. Arriba). The seeds were evenly distributed in the pots and covered with the 50 grams of soil that had been removed before fertilization took place. The pots were covered with plastic to reduce evaporation. The pots were checked daily to assure that the soil remained moist. Upon emergence, the pots were uncovered so as to prevent the development of spindly plants. After the plants had reached approximately a 10 cm. height they were thinned to 12 plants per pot.

Daily Management

All pots were weighed daily and brought to field capacity with distilled water. The greenhouse lights were set to allow 15-16 hours of daylight. Pots were rotated 1/3 of the way around the table every third

or fourth day to assure that all pots were subject to the same lighting.

Harvest

Western wheatgrass was harvested approximately 48 days after planting. This procedure entailed cutting the plants at about 2 cm. above the soil surface. Plants were then washed in .1 N HCl acid bath, rinsed twice in distilled water, placed in brown paper bags and dried at 60 degrees Centigrade for 48 to 60 hours. Before harvesting, the plants were measured and average height was recorded. After drying in a forced air oven, the plants were weighed.

PART II

PLANT GROWTH SUITABILITY EVALUATION BASED ON LABORATORY CHARACTERIZATION

This portion of the evaluation and characterization study involved two steps. An initial evaluation was performed to identify the chemical and/or physical problems associated with the materials that influence plant growth. This resulted in the development of "Problem Identification Categories." Secondly, the "Problem Identification Categories" were further grouped into what are described as "Problem Area Groups." The purpose of this latter grouping was to identify particular problem areas such as fertility, salinity, etc., which are more meaningful for evaluating the magnitude of potential long term management and/or environmental considerations. Following is described the evaluation process used for interpreting plant growth suitability on the basis of laboratory characterization data.

Development of Problem Identification Categories

Basic to determining plant growth suitability is the identification of the specific kinds of problems that affect the use of a material for this purpose. First, it is essential to evaluate those chemical and physical properties most important in affecting plant growth. Next, criteria must be established for making a suitability interpretation. The properties considered and criteria used for interpretation in this part of the study are shown in Table 1. The chemical and physical data used for this evaluation are shown in Appendix Table 1. This step in the evaluation process resulted in an identification of 80 "Problem Identification Categories" which are described in Table 2.

Table 1. Criteria for evaluating laboratory characterization data for determining plant growth suitability.

Criteria for evaluating the following overburden characteristics were developed using proposed guidelines developed by the Western Regional Soil Survey Work Planning Committee on "Guidelines for Evaluating Soil and Overburden Characteristics in Strip-Mine Reclamation.

Texture

Texture Class		Rating
very fine sandy loam	(vfsl)	good
fine sandy loam	(fsl)	good
sandy loam	(sl)	good
loam	(l)	good
silt loam	(sil)	good
loamy fine sand	(lfs)	fair
loamy sand	(ls)	fair
clay loam	(cl)	fair
sandy clay loam	(scl)	fair
silty clay loam	(sicl)	fair
sand	(s)	poor
clay	(c)	poor
sandy clay	(sc)	poor
silty clay	(sic)	poor

pH

pH	Rating
6.0-8.4	good
5.0-6.0; 8.4-8.9	fair
<5.0; >8.9	poor

Boron

Soil Test - ppm B	Rating
0-8	acceptable
>8.0	unacceptable (potentially toxic to plants and environmentally unacceptable)

The following criteria are based on current Colorado State University Soil Testing Laboratory soil interpretation guidelines.

Available Phosphorus

Soil Test - ppm P	Soil Phosphorus Fertility Status
0-7	deficient
>7	adequate

Available Potassium

Soil Test - ppm K	Soil Potassium Fertility Status
0-60	deficient
>60	adequate

Available Nitrogen

Soil Test - ppm NO_3N	Soil Nitrogen Fertility Status
0-40	low-deficient
>40	adequate

Organic matter (organic carbon data) was not used for evaluating the nitrogen supplying ability of the overburden materials because of lack of data concerning the C: N ratios or type of organic materials present. We are quite certain that the nature of organic materials found in the overburden materials is quite different from that found in surface soils, thus any attempt to evaluate the relationship between organic carbon and nitrogen as related to plant growth would be meaningless. As a result, only NO_3-N was used as an indicator of nitrogen status.

Available Zinc

Soil Test - ppm Zn	Availability Status
0-0.5	potentially deficient
>0.5	adequate

Available Iron

Soil Test - ppm Fe	Availability Status
0-2.0	potentially deficient
>2.0	adequate

Available Copper and Manganese

Soil Test - ppm Cu or Mn	Availability Status
0-0.5	potentially deficient
>0.5	adequate

Salinity

Soil Test - mmhos/cm	Rating
0-4	acceptable
4-8	marginal
>8	poor to unsuitable

Sodium

Exchangeable Sodium Percent	Rating
0-10	acceptable
10-15	marginal
>15	non-acceptable

Table 2. Description of "Problem Identification Categories."

Problem Identification Categories	Bore Hole Identification Number	Description
1	3-5; 5-7	N-P deficient; Mg to Ca ratio > 1.0
2	5-17	N-P-K deficient
3	4-15, 4-20; 5-4, 5-5; 6-18, 6-53	N-P-K deficient; Mg to Ca ratio > 1.0
4	4-10	N-P-K deficient; Cu deficient
5	4-14; 5-16, 5-20; 6-51	N-P-K deficient; Cu deficient; Mg to Ca ratio > 1.0
6	5-9; 6-17	N-P-K deficient; Mn deficient; Mg to Ca ratio > 1.0
7	6-4	N-P-K deficient; Zn-Cu deficient; Mg to Ca ratio > 1.0
8	6-3	N-P deficient; fair texture
9	5-12; 6-11	N-P deficient; fair texture; Mg to Ca ratio > 1.0
10	5-1	N-P-K deficient; Mn deficient; fair texture; Mg to Ca ratio > 1.0
11	3-1, 3-2	N-P-K deficient; fair texture; Mg to Ca ratio > 1.0
12	4-2, 4-13	N-P-K deficient; Cu deficient; fair texture; Mg to Ca ratio > 1.0
13	3-3, 3-4; 5-22	N-P-K deficient Cu deficient; fair texture; Mg to Ca ratio 1.0
14	5-23	N-P-K deficient; Zn-Cu deficient; fair texture; Mg to Ca ratio > 1.0
15	4-3	N-P-K deficient; fair pH; fair texture; Mg to Ca ratio > 1.0
16	6-32	N-P-K deficient; Cu deficient; fair pH; fair texture
17	6-7	N-K deficient; fair pH; fair texture; Mg to Ca ratio > 1.0
18	6-20	N-P deficient; poor texture
19	5-18; 6-10	N-P deficient; poor texture; Mg to Ca ratio > 1.0

Table 2. (continued)

Problem Identification Categories	Bore Hole Identification Number	Description
20	5-8B, 5-10	N-P deficient; Mn deficient; poor texture; Mg to Ca ratio >1.0
21	5-8A	N-P deficient; Cu-Mn deficient; poor texture; Mg to Ca ratio >1.0
22	6-1	N-P-K deficient; poor texture; Mg to Ca ratio >1.0
23	6-57	N-P-K deficient; Cu deficient; poor texture
24	6-5	N-P-K deficient; Zn-Cu deficient; poor texture; Mg to Ca ratio >1.0
25	4-19; 5-15	N-P-K deficient; moderate salinity; Mg to Ca ratio >1.0
26	4-1	N-P-K deficient; Cu deficient; moderate salinity
27	6-56	N-P deficient; moderate salinity; fair texture; Mg to Ca ratio >1.0
28	4-8	N-P-K deficient; Cu deficient; moderate salinity; fair texture
29	3-19	N-P deficient; Cu deficient; moderate salinity; high pH; fair texture
30	5-14A	N-P deficient; moderate salinity; fair pH; fair texture; Mg to Ca ratio >1.0
31	4-5	N-P-K deficient; moderate salinity; moderate sodium
32	5-28	N-P-K deficient; moderate sodium; fair texture
33	6-19	N-P deficient; moderate sodium, fair texture
34	5-13	N-deficient; moderate salinity; poor texture
35	6-12	N-P deficient; moderate salinity; poor texture; Mg to Ca ratio >1.0
36	4-17	N-P deficient; Mn deficient; moderate salinity; poor texture; Mg to Ca ratio >1.0
37	5-3	N-P-K deficient; Mn deficient; moderate salinity; poor texture; Mg to Ca ratio >1.0
38	5-14B	N-P deficient; moderate salinity; fair pH; poor texture; Mg to Ca ratio >1.0
39	6-16	N-P deficient; moderate salinity; moderate sodium; fair pH, poor texture; Mg to Ca ratio >1.0
40	5-27	N-P deficient; moderate sodium; poor texture; Mg to Ca ratio >1.0

Table 2. (continued)

Problem Identification Categories	Bore Hole Identification Number	Description
41	4-16	N-P deficient; moderate salinity; poor pH; Mg to Ca >1.0
42	6-13; 6-14	N-P deficient; moderate salinity; poor pH; poor texture; Mg to Ca ratio >1.0
43	3-7; 4-9A	N-P deficient; moderate salinity; high sodium; fair texture; Mg to Ca ratio >1.0
44	3-8	N-P deficient; Cu deficient; moderate salinity; high sodium; fair texture; Mg to Ca ratio >1.0
45	6-29	N-P deficient; high salinity; high sodium; fair texture
46	4-0B	N-P deficient; high salinity; high sodium; fair texture; Mg to Ca ratio >1.0
47	3-20	N-P deficient; Cu deficient; high salinity; high sodium; fair texture
48	3-17A	N-P deficient; Cu deficient; high salinity; high sodium; fair texture
49	3-18	N-P deficient; Cu deficient; high salinity; high sodium; fair pH; fair texture
50	3-9, 3-10, 3-11	N-P deficient; moderate salinity; high sodium; poor texture; Mg to Ca ratio >1.0
51	6-41	N-P deficient; moderate salinity; high sodium; fair pH; poor texture
52	3-15	N-P deficient; moderate salinity; high sodium; high ph; poor texture; Mg to Ca ratio >1.0
53	3-14	N-P deficient; Cu deficient; moderate salinity; high sodium; fair pH; poor texture; Mg to Ca ratio >1.0
54	6-8	N-P deficient; Cu deficient; high salinity; poor pH; Mg to Ca ratio >1.0
55	5-19; 6-9	N-P-K deficient; high salinity; poor pH; fair texture; Mg to Ca ratio >1.0
56	4-12	N-P-K deficient; Cu deficient; high salinity; poor pH; fair texture; Mg to Ca ratio >1.0

Table 2. (continued)

Problem Identification Categories	Bore Hole Identification Number	Description
57	3-13	N-P deficient; high salinity; high sodium; poor texture; Mg to Ca ratio >1.0
58	3-17B	N-P deficient; Cu deficient; high salinity; high sodium; poor texture; Mg to Ca ratio >1.0
59	3-16	N-P deficient; high salinity; high sodium; poor texture; fair pH; Mg to Ca ratio >1.0
60	4-6	N-P deficient; high sodium
61	4-11	N-P deficient; high sodium; Mg to Ca ratio >1.0
62	6-21	N-P-K deficient; Mn deficient; high sodium
63	6-31	N-P deficient; high sodium; fair pH
64	6-30	N-P deficient; Zn deficient; high sodium; fair pH
65	6-28	N-P-K deficient; Cu deficient; high sodium; fair pH; fair texture
66	4-7	N-P deficient; high sodium; fair pH; fair texture
67	6-37, 6-39, 6-40, 6-45, 6-48	N-P deficient; high sodium; fair pH; fair texture
68	6-25	N-P deficient; Zn-Mn deficient; high sodium; fair pH; fair texture
69	6-23	N-P deficient; Mn deficient; high sodium; fair texture
70	6-43	N-P deficient; high sodium; poor pH; fair texture
71	5-26	N-P-K deficient; Fe deficient; high sodium; poor texture; Mg to Ca ratio >1.0
72	5-25	N-P-K deficient; Zn-Fe-Mn-Cu deficient; high sodium; poor texture
73	6-22, 6-24	N-P deficient; Mn deficient; high sodium; poor texture
74	6-27, 6-29, 6-35	N-P deficient; high sodium; fair pH; poor texture
75	6-36	N-P deficient; Mn deficient; high sodium; fair pH; poor texture
76	6-46, 6-47	N-P deficient; high sodium; poor pH; poor texture
77	6-15	N-P deficient; high salinity; poor pH; poor texture; Mg to Ca >1.0

A study of these categories indicates that the following specific kinds of limitations exist in terms of the suitability of the materials studied as plant growth media.

1. Nitrogen deficiency is common to nearly all materials.

2. Phosphorous deficiency is common to nearly all materials.

3. Potassium deficiency is common to a large percentage of materials.

4. Micronutrient deficiencies are common. Copper and zinc are most common and manganese to a lesser degree. It is important to note that the criteria used for evaluating micronutrient deficiencies are based on deficiencies associated with agronomic crops sensitive to these elements. Thus, the micronutrient interpretations must be considered somewhat arbitrary. Our main concern would be the effect of low copper in materials where Mo levels may be high. Data provided later in this report indicates that the Mo level is quite low in most materials. Overall, we suspect that micronutrients would not be a major fertility problem.

5. Texture has been identified as being a potential concern with a large number of materials. Low available water holding capacity and fertility would be the major problems associated with the coarse textured materials. High runoff potential and erosion would be major problems associated with the coarse textured materials. The high runoff potential is a concern both as it affects environmental quality as well as plant growth.

6. Salinity is a serious problem associated with many materials.

7. Sodium problems are common to many materials.

8. Low pH must be considered as potentially limiting because of its relationship to heavy metal solubility. This is a concern both from an environmental and plant growth point of view.

9. Magnesium to calcium ratios.--There is evidence that the productivity of some plants is decreased due to a high Mg to Ca ratio in the soil. As shown in the descriptions of the "Problem Identification Categories" in Table 2, the Mg to Ca ratio in the saturation extract exceeds 1.0 in many materials. The effect of high Mg to Ca on plant growth appears to be a function of the interrelationship of several factors; namely, total concentration of Mg and Ca in soil solution, pH of the soil, bicarbonate concentration, salinity and crop species. There is insufficient data available to evaluate this factor at this time, particularly as it relates to the study area. All we can do is flag it as a potential concern.

In summary, deficiencies in nitrogen, phosphorous, potassium and possibly zinc, copper and manganese; sodium; salinity; low pH and texture appear to be the kinds of specific problems associated with the materials studied, in terms of plant growth suitability. The particular problem or combination of problems are defined for each of the "Problem Identification Categories."

Development and Description of "Problem Area Categories"

Recognizing that the number of "Problem Identification Categories" identified are too numerous for making management decisions, these categories were further grouped into "Problem Area Categories." In addition to making the data more manageable, this latter grouping allows for a comparison of materials on the basis of problem areas i.e., fertility, salinity, etc., which are more meaningful from a management decision point of view. In addition, grouping in this way better identifies the magnitude of the kinds and combinations of problems, which in turn provides a basis for developing relative suitability groups.

Descriptions of the "Problem Area Groups" and the basis used for determining a relative suitability rating are shown in Table 3.

A summary of relative suitability ratings by "Problem Area Groups" is shown in Table 4.

The suitability ratings shown in Table 4 are in the most part supported by the greenhouse and geochemical studies with the following exceptions.

1) For group 3, which we classed as questionable based on laboratory data, no growth was obtained in the greenhouse on materials representative of this group. These materials are characterized by being very coarse textured and having very low cation exchange capacity. Based on the greenhouse results, we would class these materials as unsuitable because of the apparent adverse effect of the coarse textured nature of the materials on plant growth.
2) Extractable chemical data indicate that the moderately acid nature of materials in Group 12, 17, and 18, is not a serious problem from the standpoint of mobility of heavy metals. The suitability rating for materials in this group would remain as questionable due to salinity and texture. However, we would not identify moderately low pH as a limiting factor.
3) Materials in group 15 are classed as questionable based on the laboratory characterization data. The greenhouse data on materials representative of this group was very poor (Pot 6 - yield of .07 gm/pot). The greenhouse data suggest that this material should be rated as unsuitable. More importantly, the greenhouse data may be indicating that our ratings of either questionable and/or unsuitable for materials either moderately or highly affected by sodium are legitimate. We feel that our original rating is valid.

In summary, the only real discrepancy between the greenhouse, geochemical and plant analyses data vs. the suitability ratings based on laboratory characterization data was the poor growth response obtained in the greenhouse on the coarse textured materials found in Problem Area Group 3. And the discrepancy was not major.

Finally, it may be well to point out that the term "unsuitable" may not in all cases be an appropriate term. If sufficient resources were expended, problems associated with some materials could be ameliorated. However, in most cases the ameliorative measures would not be practical.

Table 3. Descriptions of "Problem Area Groups."

Problem Area Groups	Description and Basis for Suitability Rating
1. Fertility	This group includes Problem Identification Categories 1, 2, 3, 4, 5, 6, and 7. N, P and K deficiencies either alone or in combination with Mn, Zn or Cu deficiencies affect this group of materials as a plant growth media. These materials are suitable as plant growth media if fertilizers are added to eliminate the deficiencies. Based on this criteria used for evaluation, these materials are classed as suitable for plant growth.
2. Fertility and fair texture	This group includes Problem Identification Categories 8, 9, and 10. N, P, and K, either alone or in combination, and Mn deficiencies account for the materials' fertility limitations. Silty clay loam and clay loam textures increase the materials' potential erosiveness. These materials are classed as suitable.
3. Fertility and fair texture	This group includes Problem Identification Categories 11, 12, 13 and 14. Deficiencies of N, P, and K, either alone or in combination, and Cu are the major fertility limitations. Loamy sand textures increase the materials susceptibility to wind erosion. These materials are classed as questionable because of problems associated with the coarse texture.
4. Fertility, fair pH and fair texture	This group includes Problem Identification Categories 15 and 16. Deficient levels of N, P, and K, either alone or in combination, and possible Cu are the major fertility limitations. Loamy sand textures may limit the amount of water available for plant growth and have a high wind erosion potential. These materials are classed as questionable because of texture.
5. Fertility, fair texture, and fair pH	This group includes Problem Identification Category 17. N and P deficiencies, pH values of 5.0 to 6.0 and loamy sand textures characterize the materials of this group. Potential mobility of heavy metals in the environment and/or toxicity to plants due to low pH along with low water holding capacities and potential wind erosion as a plant growth media. These materials are classed as unsuitable because of texture and low pH.

Table 3. (Continued)

Problem Area Groups	Description and Basis for Suitability Rating
6. Fertility and poor texture	This group includes Problem Identification Categories 18, 19, 20, and 21. N and P deficiencies and Mn and/or Cu deficiencies along with clayey textures characterize the materials of this group. Erosion from water may be a potential problem due to the very slow infiltration. These materials appear to be suitable from a plant growth and environmental standpoint if sufficient water is available and erosion can be controlled.
7. Fertility and poor texture	This group includes Problem Identification Categories 22, 23, and 24. N, P, and K deficiencies and Cu and/or Zn deficiencies along with sandy textures characterize the materials of this group. Wind erosion can be a potential problem due to the sandy character of these materials. These materials are classed as unsuitable due to low water holding capacity along with low inherent fertility and erosion potential.
8. Fertility and moderate salinity	This group includes Problem Identification Categories 25 and 26. N, P, and K deficiencies and moderate levels of salinity (4-8 mmhos/cm) characterize the materials of this group. Moderate salinity levels may affect plant growth unless salt tolerant species are selected. The materials are classed as questionable due to salinity.
9. Fertility, moderate salinity, and texture	This group includes Problem Identification Category 27. N and P deficiency, moderate salinity, and sandy clay loam texture characterize the materials of this group. Moderate salinity levels may effect plant growth unless salt tolerant species are selected. These materials may be classed as questionable due to the moderate salinity effects on plant growth and potential pollution to surface and subsurface water. In addition, water erosion potential is moderate to high due to fine texture.
10. Fertility, moderate salinity and fair texture	This group includes Problem Identification Category 28. N, P, K, and Cu deficiencies, moderate salinity and loamy sand texture characterize the materials of this group. Moderate salinity levels may affect plant growth unless salt tolerant species are selected and in combination with loamy sand textures, may be a potential pollution hazard to surface and subsurface water. This group may be classed as unsuitable due to the moderate

Table 3 (continued)

Problem Area Groups	Description and Basis for Suitability Rating
10. continued	salinity levels, rapid percolation rates which may affect plant growth and environmental quality and very low water holding capacity.
11. Fertility, moderate salinity, fair pH, and fair texture	This group consists of Problem Identification Category 29. N, P, and Cu deficiencies, moderate salinity, fair pH (8.4-8.9) and clay loam textures characterize the materials of this group. Moderate salinity levels may effect plant growth unless salt tolerant species are selected. Clay loam textures increase erosion hazard by reducing infiltration rates and also increase the effect of salinity on plant growth by reducing the amount of water available to leach salts from the system. These materials may be classified as questionable due to the effects of salinity and texture.
12. Fertility, moderate salinity, fair pH, and fair texture	This group consists of Problem Identification Category 30. N and P deficiencies, moderate salinity, fair pH (5.0-6.0) and sandy clay loam texture characterize the materials of this group. Moderate salinity levels may affect plant growth unless salt tolerant species are selected. Sandy clay loam textures will limit the amount of water available for leaching salts from the system by reduced infiltration rates. These materials may be classed as questionable as a plant growth media due to effects of moderate salinity levels on plant growth and potential mobility of heavy metals in the environment due to the moderately acid pH.
13. Fertility, moderate salinity, and moderate sodium	This group consists of Problem Identification Category 31. N, P, and K deficiencies, moderate salinity, and moderate sodium characterize the materials of this group. Moderate salinity levels may affect plant growth unless salt tolerant species are selected. Moderate sodium levels indirectly increase water erosion potential by reducing the amount of plant growth and decreasing infiltration rates, thus creating more runoff. Materials within this group may be classified as unsuitable due to sodium effects on plant growth and effects of increased erosion on environmental quality.
14. Fertility, moderate sodium, and fair texture	This group consists of Problem Identification Category 32. N, P, and K deficiencies, moderate sodium and loamy sand textures characterize the materials of this group. Moderate sodium levels

Table 3 (continued)

Problem Area Groups	Description and Basis for Suitability Rating
14. continued	may reduce plant growth thereby increasing the wind erosion potential of the loamy sand material. This material may be classified as unsuitable due to the potential effects of sodium and extremely low water holding capacity on plant growth.
15. Fertility, moderate sodium, and fair texture	This group consists of Problem Identification Category 33. N and P deficiencies, moderate sodium and clay loam textures characterize this group of materials. Moderate sodium levels will reduce plant growth and also decrease infiltration rates of clay loam textured materials. Water erosion becomes an increasing problem due to decreased infiltration rates. These materials are classed as questionable due to sodium.
16. Fertility, moderate salinity, poor texture	This group includes Problem Identification Categories 34, 35, 36, and 37. N, either alone or in combination with P, K and Mn deficiencies, moderate salinity and silty clay and clay textures characterize the materials of this group. Moderate levels of salinity may reduce plant growth unless salt tolerant species are selected. Clayey materials have a high water erosion potential and therefore, if erosion occurs, may effect environmental quality. These materials may be classified as questionable due to the effects of moderate salinity on plant growth and potential erosion problems.
17. Fertility, moderate salinity, fair pH, and poor texture	This group consists of Problem Identification Category 38. N and P deficiencies, moderate salinity, fair pH (5.0-6.0) and clay textures characterize the materials of this group. Moderate salinity levels may reduce plant growth unless salt tolerant species are selected. Clay materials have a high water erosion potentia l and therefore, if erosion occurs, may affect environmental qaulity. Low pH increases the potential mobility of heavy metals in the environment and/or toxicities to plants. There were no greenhouse sa mples representative of this group. These materials may be classified as questionable due to potential erosion problems and heavy metal mobility and toxicities and salinity effects.

Table 3 (continued)

Problem Area Groups	Description and Basis for Suitability Rating
18. Fertility, moderate salinity, moderate sodium, fair pH, and poor texture	This group consists of Problem Identification Category 39. N and P deficiencies, moderate salinity and sodium (ESP 10-15), fair pH (5.0-6.0) and clay textures characterize the materials of this group. Moderate salinity levels may reduce plant growth unless salt tolerant species are selected. Sodium levels will reduce plant growth and in association with clay textured materials, will reduce infiltration and permeability rates to very low levels, thus increasing the erosion potential. These materials may be classed as unsuitable due to the moderate salinity, sodium levels, clayey textures and moderate acid pH.
19. Fertility, moderate sodium, and poor texture	This group consists of Problem Identification Category 40. N and P deficiencies, moderate sodium and clay texture characterize the materials of this group. Moderate sodium levels may reduce plant growth and when associated with clayey textures, reduces permeability and infiltration thus increasing erosion potential. Due to the moderate sodium levels and clayey nature of the materials, the group is classified as questionable.
20. Fertility, moderate salinity, and poor pH	This group consists of Problem Identification Category 41. N and P deficiencies, moderate salinity, and poor pH (<5.0) characterize the materials of this group. Moderate salinity levels may reduce plant growth unless salt tolerant species are selected. Low pH increases the potential mobility of heavy metals in the environment and increases potential toxicities to plants. Due to the environmental concerns associated with low pH, and moderate salinity levels, these materials may be classified as unsuitable.
21. Fertility, moderate salinity, poor pH and poor texture	This group consists of Problem Identification Category 42. N and P deficiencies, moderate salinity, poor pH (<5.0) and clay textures characterize the materials of this group. Moderate salinity may reduce plant growth unless salt tolerant species are selected. Clayey textured materials are very water erosive and therefore, if erosion does occur, may effect environmental quality. Low pH increases the potential mobility of heavy metals in the environment and also increases potential toxicities to plants. Due to moderate salinity effects on plant growth, erosive nature of clayey

Table 3 (continued)

Problem Area Groups	Description and Basis for Suitability Rating
21. continued	materials and low pH effects on mobility of heavy metals in the environment and plant uptake, this material may be classed as unsuitable.
22. Fertility, moderate salinity, high sodium, and fair texture	This group consists of Problem Identification Categories 43 and 44. N and P deficiencies along with Cu deficiencies, moderate salinity, high sodium (ESP >15) and silty clay loam and clay loam textures characterize the materials of this group. High sodium levels will reduce plant growth and in association with silty clay loam and clay loam textures will decrease infiltration and permeability to very low levels. As a result of this decreased permeability, water erosion potential is increased. Due to the high sodium effect of reduced plant growth and increased erosion potential this material might be classed as unsuitable.
23. Fertility, high salinity, high sodium, and fair texture	This group includes Problem Identification Categories 45, 46, 47, and 48. N, P, and Cu deficiencies, high salinity, (>8 mmhos/cm), high sodium and clay loam textures characterize the materials of this group. High salinity and high sodium levels will restrict plant growth on all but the most salt and sodium tolerant species. Clay loam textures in association with high sodium levels will reduce infiltration rates and increase erosion potential. Due to the detrimental effects of salinity and sodium on plant growth and increased erosion potential of the materials, this group may be classed as unsuitable.
24. Fertility, high salinity, high sodium, fair pH and fair texture	This group consists of Problem Identification Category 49. N, P, and Cu deficiencies, high salinity, high sodium, fair pH (8.4-8.9), and clay loam textures characterize the materials of this group. High salinity and sodium levels will restrict plant growth on all but the most sodium and salt tolerant species. Clay loam textures in association with high sodium levels will reduce infiltration and permeability rates thus increasing the erosion potential of the materials. Due to the effect of high salinity and sodium on plant growth and potential erosion problems this material may be classed as unsuitable.

Table 3 (continued)

Problem Area Groups	Description and Basis for Suitability Rating
25. Fertility, moderate salinity, high sodium, and poor texture	This group consists of Problem Identification Category 50. N and P deficiencies, moderate salinity, high sodium, and clay texture characterize the materials of this group. Moderate salinity and high sodium levels will restrict plant growth on all but salt and sodium tolerant species. Clay textured material in association with high sodium will be almost impervious to water and therefore very highly erosive. Due to the high sodium and moderate salinity levels potential effects on plant growth and infiltration rates, this group is classed as unsuitable.
26. Fertility, moderate salinity, high sodium, fair pH and poor texture	This group includes Problem Identification Categories 51, 52, and 53. N and P deficiencies with or without Cu deficiences, moderate salinity, high sodium, fair pH (8.4-8.9) and clayey textures characterize the materials of this group. Moderate salinity and high sodium levels will restrict plant growth on all but sodium and salt tolerant species. Clay textured materials in association with the high sodium levels will become almost impervious to water and therefore, very highly erosive. Dut to the high sodium and moderate salinity levels on plant growth and infiltration rates, this group is classed as unsuitable.
27. Fertility, high salinity, and poor pH	This group consists of Problem Identification Category 54. N, P, and Cu deficiencies, high salinity, and pH values less than 5.0 characterize the materials of this group. High salinity levels will reduce or restrict plant growth unless salt tolerant species are selected. Low pH increases the potential mobility of heavy metals in the environment and increases potential toxicities to plants. Due to the high salinity and low pH effects on plant growth and environmental quality, this material is classed unsuitable.
28. Fertility, high salinity, poor pH, and fair texture	This group consists of Problem Identification Category 55. N, P and K deficiencies, high salinity, pH values less than 5.0 and sandy clay loam textures characterize the materials of this group. High salinity levels will reduce or restrict plant growth unless salt tolerant species are selected. Low pH increases the potential mobility of heavy metals in the environment and increases potential toxicities to plants. Due to the high salinity a nd low pH, this material is classed as unsuitable.

Table 3 (continued)

Problem Area Groups	Description and Basis for Suitability Rating
29. Fertility, high salinity, poor pH, and fair texture	This group consists of Problem Identification Category 56. N, P, K, and Cu deficiencies, high salinity, pH values less than 5.0 and loamy sand textures characterize the materials of this group. High salinity levels will reduce plant growth unless salt tolerant species are selected. Low pH increases the potential mobility of heavy metals in the environment and increases potential plant toxicities. Loamy sand textures are highly erosive by wind when left bare or denude of vegetation. Due to the effects of high salinity and low pH, this material is classed as unsuitable.
30. Fertility, high salinity, high sodium and poor texture	This group includes Problem Identification Categories 57 and 58. N and P deficiencies with or without Cu deficiencies, high salinity, high sodium and clay textures characterize the materials of this group. High sodium and salinity levels will reduce or restrict plant growth on all but the most salt and sodium tolerant species. Clayey textured materials associated with high sodium levels are very erosive due to the reduced infiltration and permeabilities caused by the sodium condition. Due to the effects of high salinity, high sodium, and the erosion potential of these materials, they are classed as unsuitable.
31. Fertility, high salinity, high sodium, fair pH and poor texture	This group consists of Problem Identification Category 59. N and P deficiencies, high salinity, high sodium, fair pH (8.4-8.9) and clay textures characterize the materials of this group. High salinity and high sodium levels will reduce or restrict plant growth on all but the most salt and sodium tolerant species. Clayey textured materials associated with high sodium levels tend to reduce infiltration and permeability rates, thus increasing the erosion potential. Due to the effects of high salinity, sodium levels, and the erosion potential, these materials are classed unsuitable.
32. Fertility and high sodium	This group includes Problem Identification Categories 60, 61, and 62. N and P and/or K and Mn deficiencies and high sodium characterize the materials of this group. High sodium levels will reduce or restrict plant growth on all but the most sodium tolerant species. Erosion potential are greatly increased due to the effect of sodium on reducing permeability and infiltration of water. These materials are classed as unsuitable.

Table 3 (continued)

Problem Area Groups	Description and Basis for Suitability Rating
33. Fertility, high sodium, and fair pH	This group includes Problem Identification Categories 63 and 64. N and P with or without Zn deficiencies, high sodium and fair pH (8.4-8.9) characterize the materials of this group. High sodium levels will reduce or restrict plant growth on all but the most sodium tolerant species. Erosion potential is increased due to the effect of sodium on reducing permeability and infiltration of water. These materials are classed as unsuitable.
34. Fertility, high sodium, fair pH, and fair texture	This group consists of Problem Identification Category 65. N, P, K, and Cu deficiencies, high sodium, fair pH (8.4-8.9) and loamy sand textures characterize the material of this group. High sodium levels will reduce or restrict plant growth on all but the most sodium tolerant species. Coarse textured materials such as loamy sands have a high wind erosion potential if vegetative cover is sparse and have very low water holding capacity. These materials may be classed as unsuitable.
35. Fertility, high sodium, fair pH, and fair texture	This group includes Problem Identification Categories 66, 67, and 68. N and P deficiencies, with or without Zn and Mn deficiencies, high sodium, fair pH (8.4-8.9) and clay loam textures characterize the materials of this group. High sodium levels will reduce or restrict plant growth on all but the most sodium tolerant species. Permeability and infiltration of water are reduced on moderately fine textured materials such as a clay loam due to the dispersive effects of sodium on clay particles. This effect will tend to increase erosion potential within this group. These materilas are classed unsuitable.
36. Fertility, high sodium, fair texture	This group consists of Problem Identification Category 69. N, P, and Mn deficiencies, high sodium and clay loam textures characterize the materials of this group. High sodium levels will reduce or restrict plant growth on all but the most sodium tolerant species. Infiltration and permeability of water are reduced on moderately fine textured materials such as clay loams due to the dispersive effect of sodium on clay particles. This effect will tend to increase erosion potential. These materials are classed as unsuitable.

Table 3 (continued)

Problem Area Groups	Description and Basis for Suitability Rating
37. Fertility, high sodium, poor pH, and fair texture	This group consists of Problem Identification Category 70. N and P deficiencies, high sodium, pH values greater than 8.9 and silty clay loam texture characterize the material of this group. High sodium levels will reduce or restrict plant growth on all but the most tolerant species. Infiltration and permeability of water are reduced on moderately fine textured materials such as silty clay loams, due to the dispersive effect of sodium or clay particles. This effect will tend to increase water erosion potential. These materials are classed unsuitable.
38. Fertility, high sodium, and poor texture	This group includes Problem Identification Categories 71 and 72. N, P, and K deficiencies along with any combination of Fe, Zn, Cu and Mg deficiencies, high sodium and sandy texture characterize the materials of this group. High sodium levels will reduce or restrict plant growth on all but the most sodium tolerant species. Sandy textures will increase the problem of initiating and sustaining plant growth due to their very low water holding capacities. These materials are classed unsuitable.
39. Fertility, high sodium, and poor texture	This group consists of Problem Identification Category 73. N, P, and Mn deficiencies, high sodium and clayey textures characterize the material of this group. High sodium levels will reduce or restrict plant growth on all but the most sodium tolerant species. Clayey textured materials become almost impervious to water due to the dispersal effects of sodium on clay particles. This effect will increase the erosion potential of the already very erosive materials. These materials are classed as unsuitable.
40. Fertility, high sodium, fair pH and poor texture	This group includes Problem Identification Categories 74 and 75. N and P deficiencies, with or without Mn deficiencies, high sodium, fair pH (8.4-8.9) and clayey textures characterize the materials of this group. High sodium levels will reduce or restrict plant growth on all but the most sodium tolerant species. Clayey textured materials become almost impervious to water due to the dispersive effects of sodium on clay particles. This effect will increase the erosion potential of the already very erosive materials. These materials are classed unsuitable.

Table 3 (continued)

Problem Area Groups	Description and Basis for Suitability Rating
41. Fertility, high sodium, poor pH, and poor texture	This group consists of Problem Identification Category 76. N and P deficiencies, high sodium, pH values greater than 8.9 and clayey textures characterize the materials of this group. High sodium levels will reduce or restrict plant growth on all but the most sodium tolerant species. Clay textured materials become almost impervious to water due to the dispersive effects of sodium on clay particles. This effect will increase the erosion potential of the already very erosive materials within this group. These materials are classed unsuitable.
42. Fertility, high salinity, poor pH, and poor texture	This group consists of Problem Identification Category 77. N and P deficiencies, high salinity, pH values less than 5.0 and clayey textures characterize the materials within this group. High salinity levels will reduce or restrict plant growth unless salt tolerant species are selected. Low pH increases the potential mobility of heavy metals in the environment and increases the potential plant toxicities. Clayey textured materials are very highly erosive to water due to the very slow and slow infiltration rates. The materials within this group are classed unsuitable.

Table 4. Summary of Suitability Ratings developed on the Basis of Laboratory Characterization Data.

Problem Area Group No.	Relative Rating
1	Suitable
2	Suitable
3	Questionable
4	Questionable
5	Unsuitable
6	Suitable
7	Unsuitable
8	Questionable
9	Questionable
10	Unsuitable
11	Questionable
12	Questionable
13	Unsuitable
14	Unsuitable
15	Questionable
16	Questionable
17	Questionable
18	Unsuitable
19	Questionable
20	Unsuitable
21	Unsuitable
22	Unsuitable
23	Unsuitable
24	Unsuitable
25	Unsuitable
26	Unsuitable
27	Unsuitable
28	Unsuitable
29	Unsuitable
30	Unsuitable
31	Unsuitable

Table 4. (continued)

Problem Area Group No.	Relative Rating
32	Unsuitable
33	Unsuitable
34	Unsuitable
35	Unsuitable
36	Unsuitable
37	Unsuitable
38	Unsuitable
39	Unsuitable
40	Unsuitable
41	Unsuitable
42	Unsuitable

PART III

GEOCHEMICAL EVALUATION

In addition to these chemical data shown in Appendix Table 1, analyses were carried out to identify both total and extractable amounts of other chemical characteristics for the purpose of better describing the geochemical nature of the materials studied.

Considering the arid nature of the climate in the area where the study site occurs, it becomes apparent that the bio-geochemical environment can best be described as one of low intensity. Potential lack of leaching, low rate and intensity of biological, chemical and physical weathering processes as dictated by the climatic environment suggests that significant changes in the chemical and physical nature of materials due to bio-geochemical weathering is unlikely. Or more importantly, even if changes do occur, they will occur very slowly. Thus it appears that primary emphasis on the evaluation of the geochemical nature of the materials should be made based on an approximation of the availability to plants and mobility in the environment of chemical constituents as related to the present state of the system. Using this rationale, primary emphasis was placed on "extractable" rather than total concentration for the elements considered in this section of the report. In addition, it appears that since geochemical data on the basis of total concentration will be forthcoming at some later time due to efforts of the U.S. Geological Survey, it is critical that our study evaluate the geochemical nature of the materials on the basis of the "state of the system."

Following is an appraisal, first, of geochemical data based on DTPA and ammonium bicarbonate - DTPA extractable analyses on all materials evaluated under Part II of this study and second, an evaluation of total concentrations of selected elements found in selected materials.

Geochemical Evaluation of Selected Elements - Extractable Basis

The extractable chemical analyses data are shown in Table 4. Extractable Zn, Cu, Mn and Fe were determined using a DTPA extract. All other elements shown were determined from an ammonium bicarbonate - DTPA extract. Data for the materials analyzed are shown on the basis of the "Problem Area Groups" described in Part II of this report. We grouped the materials in this manner in an attempt to determine the relationship between the amounts of the elements considered in this portion of the study vs. the chemical and physical characteristics which were used in determining plant growth suitability. Mean concentration, range and standard deviations of the concentration of each element on the basis of "Problem Area Groups" also are given. These data are shown in Table 5.

A summary of the extractable geochemical data shown in Table 5 indicates the following important relationships.

1. The evaluation of materials with respect to effect of moderate to high acidity on the mobility of heavy metals in the environment is well supported by the extractable geochemical data. This factor was identified as a potential problem for materials in Groups 5, 12, 17, 18, 20, 21, 27, 28, 29, and 42 and an examination of the data in Table 5 indicates that the extractable Al, Ni, Zn, Fe, Mn, and Cu are consistently higher in these groups as compared to materials with an alkaline environment.

2. In general, extractable Se, As and B were higher in the groups identified as having salinity problems. This only confirms our existing knowledge that these elements which usually accumulate as evaporites are often associated with deposits which contain relatively high levels of soluble salts.
3. Potential high Mo availability to plants or mobility in the environment normally is associated with highly alkaline environments. The extractable data indicate that Mo levels are relatively low and do not indicate any potential problem.
4. Standard deviations indicate that for most elements other than those already discussed, there appears to be no consistent relationship between the "Problem Area Groups" and the elements studied.
5. In general, extractable Pb levels appear to be higher in materials with low pH. However, this relationship is not consistent. Pb levels appear to be as high or higher in some alkaline materials as compared to the low pH materials. The extractable Pb levels in some materials are higher than what have been reported as the mean total concentration for most soils (10.0 ppm) or geologic materials (5 to 20 ppm). Because of the apparent randomness in Pb concentration as a function of pH and other chemical characteristics, as well as the abnormally high levels in some materials, we must consider that either contamination or error in the analyses have affected the results. We are not sure that the Pb data reflect the real situation that exists. Further evaluations are required to resolve this problem. We suspect that with the method used, that high Al and high Fe may influence the

determination of Pb. However, there is no direct evidence from the data that high Pb contents were always associated with high Al and Fe.

In summary, it is important to note that even though extractable chemical analyses data more closely approximate the actual soil solution condition than do total analyses, we must recognize the limitations of the former in terms of predictive capability. Several factors must be kept in mind are:

1. Very little data is available that correlates plant uptake with extractable levels of elements, particularly with regard to native species.
2. The extractant used in this study has a pH of 7.6, thus this effect on the extractability of elements from soil or overburden materials which are acid is not well documented.
3. Most methods, such as the method used in this part of the study, are still being investigated relative to the effects of interferences of various elements one one another and the resulting data.
4. Based on the above considerations, we feel that the interpretations provided in this portion of the study are valid. However, to interpret the data further would be risky and may lead to faulty conclusions.

Table 5. DTPA - NH_4HCO_3 Extractable B, Pb, As, Se, Al, Ni, Mo, Cd, Sr, Zn, Fe, Mn, and Cu materials from Bore Holes 3, 4, 5, and 6.

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
1.	3-5	1.36	.718	.04	.23	.53	.27	.03	.01	.34	.04	74.0	1.28	24.6	2.0	.55
	4-10	.11	.92	.05	.14	2.22	.18	.04	.08	.33	.04	5.80	3.47	3.16	2.93	0.22
	4-14	.30	.96	.13	.23	.99	.32	.03	.02	.28	.03	7.02	2.32	27.2	3.50	.46
	4-15	.29	1.30	.11	.18	1.58	.30	.03	.02	.37	.02	7.58	4.9	34.6	1.85	.53
	4-20	.27	2.08	.20	.27	1.50	.79	.04	.02	.86	.04	1.68	5.16	43.2	2.56	.74
	5-4	.29	2.52	0	.14	.51	.06	.02	.02	.03	.05	1.470	1.40	3.32	2.44	1.09
	5-5	.28	1.71	.04	.20	1.19	.16	.02	.02	.11	.05	1.93	.75	1.84	3.10	1.06
	5-7	.76	.49	.11	.21	.53	.15	.02	.02	.05	.03	2.72	2.3	4.86	2.44	.92
	5-9	.32	1.43	.11	.15	1.83	.04	.02	.01	.01	.02	.856	.99	2.90	.21	1.11
	5-16	.31	7.08	.12	.28	1.13	.13	.03	.02	.15	.08	1.870	.62	19.9	9.56	.48
	5-17	.12	1.08	.09	.28	1.22	.11	.03	.02	.13	.08	1.97	.63	11.6	6.20	.51
	5-20	.30	3.04	.16	.34	1.47	.41	.05	.03	.35	.07	6.62	2.98	37.2	4.32	.38
	6-4	.13	1.26	.04	.26	.72	.16	.03	.02	.04	.04	1.11	.47	14.8	3.52	.35
	6-17	.71	6.480	.14	.27	.44	.37	.03	.02	.27	.03	8.52	2.34	38.4	5.90	1.74
	6-18	.50	3.40	.13	.28	.99	.31	.03	.03	.38	.03	5.94	3.39	38.9	5.71	.84
	6-51	.53	9.26	.07	.20	1.81	.10	.01	.03	.09	.02	2.88	1.20	7.16	.72	.15

Table 5. (continued)

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
1.	6-53	.32	1.62	.21	.33	1.50	.16	.04	.03	.19	.05	1.69	3.54	74.2	6.10	1.41
	6-54	.18	1.76	.13	.25	1.80	.16	.03	.03	.31	.03	1.63	10.1	27.0	3.98	.32
		$\bar{x}$=.39	$\bar{x}$=2.62	$\bar{x}$=.10	$\bar{x}$=.24	$\bar{x}$=1.22	$\bar{x}$=.23	$\bar{x}$=.03	$\bar{x}$=.02	$\bar{x}$=.22	$\bar{x}$=.04	$\bar{x}$=7.51	$\bar{x}$=2.65	$\bar{x}$=23.06	$\bar{x}$=3.72	$\bar{x}$=.71
		s=.30	s=2.47	s=.06	s=.06	s=.53	s=.18	s=.01	s=.01	s=.20	s=.02	s=16.78	s=2.36	s=19.27	s=2.28	s=.43
		Range .11-1.35	Range .49-9.26	Range 0-.21	Range .14-.34	Range .44-1.83	Range .11-.41	Range .01-.04	Range .01-.03	Range .03-.86	Range .02-.08	Range 1.11-74.0	Range .47-10.1	Range 1.84-74.2	Range .72-9.56	Range .15-1.74
2.	5-1	1.01	.91	.16	.41	1.09	.16	.05	.03	.01	.06	5.76	.46	1.57	.16	.69
	5-12	.53	3.76	.09	.35	.47	.24	.04	.06	.30	.05	11.42	6.24	8.46	4.72	4.02
	6-3	.16	1.52	0	.28	.62	.35	.03	.15	.06	.05	2.24	1.07	5.56	2.94	1.51
	6-11	.82	1.45	.14	.43	.77	1.03	.08	.04	.66	.05	10.64	4.76	68.6	4.46	.77
		$\bar{x}$=.63	$\bar{x}$=1.92	$\bar{x}$=.10	$\bar{x}$=.37	$\bar{x}$=.74	$\bar{x}$=.45	$\bar{x}$=.45	$\bar{x}$=.07	$\bar{x}$=.26	$\bar{x}$=.06	$\bar{x}$=7.52	$\bar{x}$=3.13	$\bar{x}$=20.30	$\bar{x}$=3.07	$\bar{x}$=1.75
		s=.37	s=1.26	s=.08	s=.07	s=.26	s=.40	s=.05	s=.06	s=.30	s=.01	s=4.32	s=1.68	s=32.27	s=2.09	s=1.56
		Range .16-1.01	Range .91-3.76	Range 0-.16	Range .28-.43	Range .47-1.09	Range .16-1.03	Range .03-.08	Range .03-.15	Range .01-.66	Range .05-.06	Range 2.24-11.42	Range .46-6.24	Range 1.57-68.6	Range .16-4.72	Range .69-4.02
3.	3-1	.09	.68	.13	.06	3.9	.22	.01	.02	.18	.02	2.12	2.3	51.4	5.11	.84
	3-2	.23	4.96	.11	.08	.97	.15	.01	.02	.11	.02	2.74	1.65	18.9	5.42	.70
	3-3	.11	1.37	.08	.07	1.28	.11	.01	.02	.06	.02	2.52	.74	24.66	5.80	.18

Table 5. (continued)

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
6.	5-8A	1.08	6.34	.31	.51	19.22	.22	.06	.05	.03	.08	2.34	2.54	8.72	.08	.40
	5-8B	1.01	3.62	.05	.43	.82	.15	.04	.03	.03	.07	2.42	3.58	7.80	.12	1.02
	5-10	.63	2.90	.09	.44	.70	.21	.05	.05	.10	.07	6.00	2.84	3.54	.43	2.30
	5-18	.46	1.76	.07	.52	.99	2.9	.06	.02	1.10	.10	8.56	7.84	19.6	.58	2.02
	6-10	.66	3.66	.11	.54	1.25	.53	.04	.04	.28	.07	13.44	3.36	52.2	1.41	.97
	6-20	1.05	7.08	.11	.61	.74	2.3	.21	.07	1.27	.07	22.4	5.08	21.0	2.32	2.26
		$\bar{x}$=.82	$\bar{x}$=4.23	$\bar{x}$=.12	$\bar{x}$=.51	$\bar{x}$=3.95	$\bar{x}$=1.05	$\bar{x}$=.08	$\bar{x}$=.04	$\bar{x}$=.47	$\bar{x}$=.08	$\bar{x}$=9.19	$\bar{x}$=4.21	$\bar{x}$=18.81	$\bar{x}$=.82	$\bar{x}$=1.65
		s=.27	s=2.06	s=.09	s=.07	s=7.48	s=1.22	s=.06	s=.02	s=.56	s=.01	s=7.69	s=1.99	s=17.76	s=.88	s=.78
		Range .46-1.08	Range 1.76-7.08	Range .05-.31	Range .43-.61	Range .70-19.22	Range .21-2.9	Range .04-.21	Range .02-.07	Range .03-1.27	Range .07-.10	Range 2.34-22.40	Range 2.54-5.08	Range 3.54-52.2	Range .08-2.32.	Range .4-2.30
7.	6-1	.16	2.4	.08	.06	2.28	.10	.01	.03	.02	.02	.48	.90	6.94	1.80	.82
	6-5	.08	1.38	.10	.07	1.62	.03	.02	.03	.01	.01	.35	.34	4.86	1.00	.25
	6-57	.17	1.20	.13	.25	.62	.20	.03	.02	.10	.05	2.60	.57	23.6	4.46	.28
		$\bar{x}$=.14	$\bar{x}$=1.67	$\bar{x}$=.10	$\bar{x}$=.13	$\bar{x}$=1.51	$\bar{x}$=.11	$\bar{x}$=.02	$\bar{x}$=.03	$\bar{x}$=.04	$\bar{x}$=.03	$\bar{x}$=1.14	$\bar{x}$=.60	$\bar{x}$=11.80	$\bar{x}$=2.42	$\bar{x}$=.45
		s=.05	s=.67	s=.03	s=.10	s=.83	s=.09	s=.01	s=.01	s=.05	s=.02	s=1.26	s=.28	s=10.27	s=1.81	s=.32
		Range .08-.17	Range 1.2-2.4	Range .08-.13	Range .06-.25	Range .62-2.28	Range .03-.20	Range .01-.03	Range .02-.03	Range .1-.10	Range .01-.05	Range .35-2.60	Range .34-.90	Range 4.86-23.6	Range 1.0-4.46	Range .25-.82

Table 5. (continued)

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
6.	5-8A	1.08	6.34	.31	.51	19.22	.22	.06	.05	.03	.08	2.34	2.54	8.72	.08	.40
	5-8B	1.01	3.62	.05	.43	.82	.15	.04	.03	.03	.07	2.42	3.58	7.80	.12	1.02
	5-10	.63	2.90	.09	.44	.70	.21	.05	.05	.10	.07	6.00	2.84	3.54	.43	2.30
	5-18	.46	1.76	.07	.52	.99	2.9	.06	.02	1.10	.10	8.56	7.84	19.6	.58	2.02
	6-10	.66	3.66	.11	.54	1.25	.53	.04	.04	.28	.07	13.44	3.36	52.2	1.41	.97
	6-20	1.05	7.08	.11	.61	.74	2.3	.21	.07	1.27	.07	22.4	5.08	21.0	2.32	2.26
		$\bar{x}$=.82	$\bar{x}$=4.23	$\bar{x}$=.12	$\bar{x}$=.51	$\bar{x}$=3.95	$\bar{x}$=1.05	$\bar{x}$=.08	$\bar{x}$=.04	$\bar{x}$=.47	$\bar{x}$=.08	$\bar{x}$=9.19	$\bar{x}$=4.21	$\bar{x}$=18.81	$\bar{x}$=.82	$\bar{x}$=1.65
		s=.27	s=2.06	s=.09	s=.07	s=7.48	s=1.22	s=.06	s=.02	s=.56	s=.01	s=7.69	s=1.99	s=17.76	s=.88	s=.78
		Range .46-1.08	Range 1.76-7.08	Range .05-.31	Range .43-.61	Range .70-19.22	Range .21-2.9	Range .04-.21	Range .02-.07	Range .03-1.27	Range .07-.10	Range 2.34-22.40	Range 2.54-5.08	Range 3.54-52.2	Range .08-2.32.	Range .4-2.30
7.	6-1	.16	2.4	.08	.06	2.28	.10	.01	.03	.02	.02	.48	.90	6.94	1.80	.82
	6-5	.08	1.38	.10	.07	1.62	.03	.02	.03	.01	.01	.35	.34	4.86	1.00	.25
	6-57	.17	1.20	.13	.25	.62	.20	.03	.02	.10	.05	2.60	.57	23.6	4.46	.28
		$\bar{x}$=.14	$\bar{x}$=1.67	$\bar{x}$=.10	$\bar{x}$=.13	$\bar{x}$=1.51	$\bar{x}$=.11	$\bar{x}$=.02	$\bar{x}$=.03	$\bar{x}$=.04	$\bar{x}$=.03	$\bar{x}$=1.14	$\bar{x}$=.60	$\bar{x}$=11.80	$\bar{x}$=2.42	$\bar{x}$=.45
		s=.05	s=.67	s=.03	s=.10	s=.83	s=.09	s=.01	s=.01	s=.05	s=.02	s=1.26	s=.28	s=10.27	s=1.81	s=/32
		Range .08-.17	Range 1.2-2.4	Range .08-.13	Range .06-.25	Range .62-2.28	Range .03-.20	Range .01-.03	Range .02-.03	Range .-1-.10	Range .01-.05	Range .35-2.60	Range .34-.90	Range 4.86-23.6	Range 1.0-4.46	Range .25-.82

Table 5. (continued)

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
8.	4-1	.25	1.84	.16	.21	.83	.24	.02	.02	.14	.04	8.40	.80	34.6	5.42	.21
	4-19	.21	3.40	.13	.16	1.04	.29	.02	.01	.38	.02	2.44	7.52	19.1	2.80	1.20
	5-15	.45	1.65	.28	.40	1.09	1.42	.04	.08	.43	.07	4.32	3.64	30.4	20.8	1.70
		$\bar{x}$=.30	$\bar{x}$=2.30	$\bar{x}$=.19	$\bar{x}$=.26	$\bar{x}$=.99	$\bar{x}$=.65	$\bar{x}$=.03	$\bar{x}$=.04	$\bar{x}$=.32	$\bar{x}$=.05	$\bar{x}$=5.05	$\bar{x}$=3.99	$\bar{x}$=28.03	$\bar{x}$=9.67	$\bar{x}$=1.04
		s=.13	s=.96	s=.08	s=.13	s=.14	s=.66	s=.01	s=.04	s=.15	s=.02	s=3.05	s=3.37	s=8.02	s=9.72	s=.76
		Range .21-.45	Range 1.65-3.40	Range .13-.28	Range .16-.40	Range .83-1.09	Range .24-1.42	Range .02-.04	Range .01-.08	Range .14-.43	Range .02-.07	Range 2.44-8.40	Range .80-7.52	Range 19.1-34.6	Range 2.8-20.8	Range .21-1.70
9.	6-56	.21	.65	.13	.40	.89	.39	.04	.06	.63	.06	5.28	10.3	21.2	10.5	1.11
10.	4-8	.15	1.51	.13	.19	.86	.03	.02	.02	.03	.04	10.38	1.26	17.7	6.90	.18
11.	3-19	.55	.54	.06	.26	.31	.05	.03	.02	.17	.05	67.62	.74	5.24	2.52	.47
12.	5-14	.43	1.11	.19	.51	1.99	.66	.06	.02	.23	.07	6.10	.60	67.8	.98	2.04
13.	4-5	.33	1.81	.08	.25	1.47	1.35	.03	.02	.57	.03	25.8	1.00	46.4	3.30	.51
14.	5-28	.14	.72	.08	.11	3.3	1.23	.01	.02	.88	.02	12.00	8.42	22.0	2.62	.62
15.	6-19	.79	6.34	.07	.36	.91	.20	.06	.04	.18	.07	13.04	4.26	17.2	3.92	.76
16.	4-17	.75	5.36	.03	.72	.49	1.82	.14	.07	1.18	.07	50.4	16.00	9.96	.34	2.52
	5-3	.56	1.22	.38	.58	4.38	1.58	.06	.12	.37	.10	6.26	1.73	53.8	0.21	1.78
	5-13	.58	2.68	.15	.97	1.15	1.85	.06	.19	1.23	.09	10.40	14.2	44.0	8.56	3.67

Table 5. (continued)

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
16.	6-12	.92	4.64	.10	.57	.77	1.82	.07	.06	1.65	.07	43.8	9.96	38.4	.28	3.20
		$\bar{x}$=.70	$\bar{x}$=3.32	$\bar{x}$=.17	$\bar{x}$=.71	$\bar{x}$=1.70	$\bar{x}$=1.77	$\bar{x}$=.08	$\bar{x}$=.11	$\bar{x}$=1.11	$\bar{x}$=.08	$\bar{x}$=27.72	$\bar{x}$=10.47	$\bar{x}$=10.47	$\bar{x}$=2.35	$\bar{x}$=2.74
		s=.17	s=1.78	s=.15	s=.08	s=1.81	x=.13	s=.04	s=.06	s=.53	s=.02	s=22.61	s=6.35	s=18.83	s=4.14	s=.82
		Range .56-.92	Range 1.22-5.36	Range .03-.38	Range .57-.97	Range .49-4.38	Range 1.58-1.85	Range .05-.14	Range .06-.19	Range .37-1.65	Range .07-.10	Range 6.26-50.4	Range 1.73-16.0	Range 9.96-53.8	Range .21-8.56	Range 1.78-3.67
17.	5-14B	.47	.83	.08	.92	1.12	.74	.08	.03	.112	.10	31.18	1.94	56.6	.88	3.26
18.	6-16	1.21	2.80	.10	.64	.82	2.06	.09	.08	1.00	.08	41.4	14.2	42.6	.50	3.56
19	5-27	.80	10.12	0	.73	.95	.19	1.46	.05	.09	.11	50.6	14.5	3.42	.80	3.00
20.	4-16	.45	7.52	.15	.40	2.36	4.32	.04	.06	4.12	.05	34.6	12.5	7.04	1.00	2.80
21.	6-13	.93	8.22	.40	.70	17.18	1.14	.09	.06	4.44	.07	35.6	9.16	165.0	.56	3.36
	6-14	1.81	1.49	.39	1.20	5.26	4.82	.09	.10	3.28	.11	40.6	9.38	390.0	1.00	4.12
		$\bar{x}$=1.37	$\bar{x}$=4.85	$\bar{x}$=.39	$\bar{x}$=.95	$\bar{x}$=11.22	$\bar{x}$=5.99	$\bar{x}$=.09	$\bar{x}$=.08	$\bar{x}$=3.86	$\bar{x}$=.09	$\bar{x}$=38.1	$\bar{x}$=9.27	$\bar{x}$=277.5	$\bar{x}$=.78	$\bar{x}$=3.74
		s=.62	x=4.76	s=.01	s=.35	s=8.43	s=1.64	s=.04	s=.03	s=.82	s=.02	s=3.54	s=.16	s=159.10	s=.31	s=.54
		Range .93-1.81	Range 1.49-8.22	Range .39-.40	Range .70-1.20	Range 5.26-17.18	Range 1.14-4.82	Range .09	Range .06-.1	Range 3.28-4.44	Range .07-.11	Range 35.6-40.6	Range 9.16-9.38	Range 165-390	Range .56-1.0	Range 3.36-4.12

Table 5. (continued)

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
22.	3-7	1.51	.73	0	.19	.51	.68	.03	.01	.45	.04	93.8	1.61	22.8	1.64	.89
	3-8	1.27	.54	0	.11	.50	.67	.04	.01	.39	.04	74.6	.95	23.8	1.43	.23
	4-9A	.79	1.49	.116	.36	.61	3.26	.10	.04	1.50	.05	62.2	4.16	38.0	3.20	.81
		$\bar{x}$=1.19	$\bar{x}$=.92	$\bar{x}$=.04	$\bar{x}$=.22	$\bar{x}$=.54	$\bar{x}$=1.53	$\bar{x}$=.06	$\bar{x}$=.02	$\bar{x}$=0.78	$\bar{x}$=.04	$\bar{x}$=76.87	$\bar{x}$=2.24	$\bar{x}$=28.2	$\bar{x}$=2.09	$\bar{x}$=.64
		s=.36	s=.50	s=.07	s=.13	s=.06	s=1.49	s=.03	s=.02	s=.063	s=.01	s=15.92	s=1.70	s=8.5	s=.97	s=.36
		Range .79-1.51	Range .54-1.49	Range 0-.116	Range .11-.36	Range .50-.61	Range .67-3.26	Range .03-.10	Range .01-.04	Range .39-1.50	Range .04-.05	Range 62.2-93.8	Range .95-4.16	Range 22.8-38.0	Range 1.43-3.20	Range .23-.89
23.	3-17A	.94	.64	0	.27	.43	.49	.03	.03	.14	.05	7.54	.97	7.56	1.43	.41
	3-20	.54	.64	.12	.36	.45	.59	.04	.02	.11	.07	9.14	.51	9.95	2.00	.42
	4-9B	.78	1.54	.09	.37	.80	2.68	.08	.04	1.41	.06	48.6	4.22	32.2	3.42	.74
	6-49	1.94	1.17	0	.20	.67	.89	.08	.03	.43	.03	36.6	3.48	93.8	7.55	3.08
		$\bar{x}$=1.05	$\bar{x}$=1.00	$\bar{x}$=.05	$\bar{x}$=.29	$\bar{x}$=.56	$\bar{x}$=1.16	$\bar{x}$=.06	$\bar{x}$=.03	$\bar{x}$=.52	$\bar{x}$=.05	$\bar{x}$=25.47	$\bar{x}$=2.30	$\bar{x}$=35.88	$\bar{x}$=3.60	$\bar{x}$=1.16
		s=.62	s=.44	s=.06	s=.09	x=.21	x=1.03	s=.03	s=.01	s=.61	s=.02	s=20.39	s=1.83	s=46.13	s=2.76	s=1.29
		Range .54-1.94	Range .64-1.54	Range 0-.12	Range .20-.37	Range .43-.80	Range .49-2.68	Range .03-.08	Range .03-.04	Range .11-1.41	Range .03-.07	Range 7.54-48.6	Range .51-4.22	Range 7.56-32.2	Range 1.43-7.55	Range .41-3.08
24.	3-18	.70	.50	0	.30	.33	.58	.03	.02	.15	.04	4.58	1.72	9.42	1.41	.41

Table 5. (continued)

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
25.	3-9	1.38	.73	0	.16	.39	.71	.03	.02	.48	.04	59.0	3.38	28.2	1.90	1.52
	3-10	1.26	2.10	0	.21	.41	1.49	.04	.01	.72	.04	41.8	4.84	29.6	1.61	2.34
	3-11	1.24	.80	0	.17	.35	1.49	.08	.02	.62	.03	32.0	4.20	26.4	1.38	.91
		$\bar{x}$=1.29	$\bar{x}$=1.21		$\bar{x}$=.18	$\bar{x}$=.38	$\bar{x}$=1.23	$\bar{x}$=.05	$\bar{x}$=.02	$\bar{x}$=.61	$\bar{x}$=.04	$\bar{x}$=44.27	$\bar{x}$=4.14	$\bar{x}$=28.07	$\bar{x}$=1.63	$\bar{x}$=1.59
		s=.07	s=.77		s=.03	x=.03	s=.45	x=.03	s=.01	s=.12	s=.01	s=13.67	s=.73	s=1.60	s=.26	s=.72
		Range 1.24-1.38	Range .73-2.10		Range .16-.21	Range .35-.41	Range .71-1.49	Range .03-.08	Range .01-.02	Range .48-.72	Range .03-.04	Range 4.58-59.0	Range 3.38-4.84	Range 26.4-29.6	Range 1.38-1.90	Range .91-2.34
26.	3-12	1.03	.92	0	.16	.32	.66	.02	.02	.34	.04	19.8	4.76	25.2	1.50	1.13
	3-14	1.13	.81	0	.11	.30	1.14	.05	.03	.45	.03	15.18	4.14	29.0	1.53	.32
	3-15	1.23	1.55	0	.08	.25	.95	.11	.02	.48	.02	12.24	5.92	27.8	1.54	.75
	6-41	1.67	.62	0	.12	.59	1.16	.08	.02	.90	.04	15.82	8.72	31.0	1.31	2.13
		$\bar{x}$=1.25	$\bar{x}$=2.36		$\bar{x}$=.12	$\bar{x}$=.36	$\bar{x}$=.98	$\bar{x}$=.07	$\bar{x}$=.02	$\bar{x}$=.55	$\bar{x}$=.03	$\bar{x}$=15.16	$\bar{x}$=5.89	$\bar{x}$=28.25	$\bar{x}$=1.47	$\bar{x}$=1.08
		s= .26	s=2.55		s=.03	s=.15	s=.23	s=.03	s=.01	s=.25	s=.01	s= 3.11	s=2.03	s=2.42	s= .11	s= .77
		Range 1.03-1.67	Range .62-1.55		Range .08-.16	Range .25-.59	Range .66-1.16	Range .02-.11	Range .02-.03	Range .34-.90	Range .02-.04	Range 12.24-19.80	Range 4.14-8.72	Range 25.2-31.0	Range 1.31-1.54	Range .32-2.13
27.	6-8	.87	3.76	21.2	4.74	1538.0	2.90	.82	.37	1.50	.08	1.59	10.4	61.2	11.5	.36

Table 5. (continued)

Problem Area Group	Sample Number	B (ppm)	Pb (ppm)	As (ppm)	Se (ppm)	Al (ppm)	Ni (ppm)	Mo (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Sr (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
28.	5-19	1.19	.72	1.35	1.71	68.4	10.10	.12	.13	10.16	.15	16.16	4.02	510.0	3.56	2.90
	6-9	.66	2.70	17.46	3.98	1118.0	1.58	.69	.26	1.01	.07	1.70	8.24	55.2	9.06	.78
		$\bar{x}$=.93	$\bar{x}$=1.71	$\bar{x}$=9.40	$\bar{x}$=2.85	$\bar{x}$=593.2	$\bar{x}$=5.84	$\bar{x}$=.41	$\bar{x}$=.19	$\bar{x}$=5.59	$\bar{x}$=.11	$\bar{x}$=8.93	$\bar{x}$=6.13	$\bar{x}$=282.6	$\bar{x}$=6.31	$\bar{x}$=1.84
		s=.37	s=1.40	s=11.39	s=1.60	s=7421.8	s=6.03	s=.39	s=.09	s=6.47	s=.05	s=10.22	s=2.98	s=321.51	s=3.89	s=1.50
		Range .66 to 1.19	Range .72 to 2.70	Range 1.35 to 17.46	Range 1.71 to 3.98	Range 68.4 to 1118.0	Range 1.58 to 10.10	Range .12 to .82	Range .13 to .17	Range 1.01 to 10.16	Range .07 to .15	Range 1.59 to 16.16	Range 4.02 to 10.40	Range 55.2 to 510.0	Range 3.56 to 11.50	Range .36 to 2.90
29.	4-12	3.40	.79	1.94	1.71	70.8	4.52	.20	.22	2.46	1.28	2.36	15.0	1940.0	14.2	.09
30.	3-13	1.11	1.39	0	.11	.33	.74	.06	.02	.40	.03	17.36	4.50	27.6	1.51	.70
	3-17B	1.00	.65	0	.21	.43	.49	.02	.02	.14	.06	11.74	1.24	5.28	2.38	.34
		$\bar{x}$=1.05	$\bar{x}$=1.02		$\bar{x}$=.16	$\bar{x}$=.38	$\bar{x}$=.61	$\bar{x}$=.04	$\bar{x}$=.02	$\bar{x}$=.27	$\bar{x}$=.04	$\bar{x}$=14.55	$\bar{x}$=2.87	$\bar{x}$=16.44	$\bar{x}$=1.95	$\bar{x}$=.52
		s=.07	x=.52		s=.07	s=.07	s=.18	s=.07	s = 0	s=.19	s=.02	s=3.97	s=2.31	s=15.78	s=.67	s=.25
		Range 1.0-1.11	Range .65-1.39		Range .11-.21	Range .33-.43	Range .49-.74	Range .02-.06	Range .02	Range .14-.40	Range .03-.06	Range 11.74-17.36	Range 1.24-4.59	Range 5.28-27.6	Range 1.51-2.38	Range .34-.70
31.	3-16	1.08	2.16	0	.12	.246	1.50	.08	.03	.41	.03	4.06	5.72	23.6	2.24	.64

Table 5. (continued)

Problem Area Group	Sample Number	ppm B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
32.	4-6	.62	1.28	.04	.18	.49	1.24	.04	.04	1.16	.03	34.2	3.98	13.9	3.22	.65
	4-11	.44	2.88	.08	.23	2.24	.12	.02	.02	.15	.03	26.8	1.41	43.2	.92	1.23
	6-21	.54	3.28	.09	.21	1.11	.08	.02	.02	.05	.03	47.8	1.13	9.2	.22	1.61
		$\bar{x}$=.53	$\bar{x}$=2.48	$\bar{x}$=.07	$\bar{x}$=.21	$\bar{x}$=1.28	$\bar{x}$=.48	$\bar{x}$=.03	$\bar{x}$=.02	$\bar{x}$=.46	$\bar{x}$=.03	$\bar{x}$=21.93	$\bar{x}$=2.17	$\bar{x}$=22.1	$\bar{x}$=1.45	$\bar{x}$=1.16
		s=.09	s=1.06	s=.03	s=.03	s=.89	s=.66	s=.01	s=.01	2=.61	s=0	s=15.30	s=1.57	s=18.42	s=1.57	s=.48
		Range .44-.62	Range 1.28-3.28	Range .04-.09	Range .18-.23	Range .49-2.24	Range .08-1.24	Range .02-.04	Range .01-.04	Range .05-1.16	Range .03	Range 26.8-47.8	Range 1.13-3.98	Range 9.2-43.2	Range .22-3.22	Range .65-1.61
33.	6-30	.97	1.06	0	.13	.79	.12	.03	.05	.40	.03	12.98	.17	29.0	.60	.99
	6-31	1.36	31.00	.08	.18	.68	.75	.07	.04	.62	.03	9.4	1.67	39.8	2.90	.69
		$\bar{x}$=1.17	x̄=16.03	$\bar{x}$=.04	$\bar{x}$=.16	$\bar{x}$=.71	$\bar{x}$=.44	$\bar{x}$=.05	$\bar{x}$=.05	$\bar{x}$=.51	$\bar{x}$=.03	$\bar{x}$=11.19	$\bar{x}$=2.92	$\bar{x}$=34.4	$\bar{x}$=1.75	$\bar{x}$=.84
		s=.28	s=21.17	2=.06	2=.134	s=.08	s=.45	s=.03	s=.01	s=.16	s=0	s=2.53	s=1.06	s=7.64	s=1.63	s=.21
		Range .97-1.36	Range 1.06-31.00	Range 0-.08	Range .13-.18	Range .68-.79	Range .12-.75	Range .03-.07	Range .04-.05	Range .40-.62	Range .03	Range 9.4-12.98	Range .17-1.67	Range 29.0-39.8	Range .60-2.90	Range .69-.99
34.	6-28	1.56	36.8	.184	.25	2.84	.14	.08	.036	.15	.03	1.75	3.66	79.6	4.68	.48
35	4-7	.90	2.60	0	.25	.45	1.69	.07	.03	1.09	.04	61.2	2.54	38.0	5.30	1.02
	6-25	1.30	1.95	0	.27	1.30	.25	.02	.01	.32	.05	21.4	.18	32.6	.50	3.02
	6-37	1.53	5.18	0	.15	.93	.42	.08	.03	.61	.03	12.40	2.66	22.6	.66	1.95
	6-39	1.84	2.12	0	.11	.76	.89	.05	.02	.62	.03	15.14	.78	15.5	.72	1.59

Table 5. (continued

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
35.	6-40	1.92	6.30	0	1.4	.77	.15	.01	.01	.16	.02	14.96	.94	28.2	8.00	1.75
	6-45	1.17	4.12	0	.07	.43	.20	.54	.01	.16	.02	50.0	4.26	35.4	3.98	1.17
	6-48	2.36	10.86	0	.20	.56	1.19	.05	.02	.73	.03	38.4	1.84	30.2	4.20	1.27
		$\bar{x}$=1.58	$\bar{x}$=.473		$\bar{x}$=.36	$\bar{x}$=.75	$\bar{x}$=.69	$\bar{x}$=.12	$\bar{x}$=.02	$\bar{x}$=.53	$\bar{x}$=.04	$\bar{x}$=30.5	$\bar{x}$=1.89	$\bar{x}$=28.9	$\bar{x}$=3.34	$\bar{x}$=1.68
		s=.50	s=3.15		s=.47	s=.31	s=.59	s=.19	s=.01	s=.34	s=.01	s=19.46	s=1.40	s=7.75	s=2.85	s=.68
		Range .90-2.35	Range 1.95-10.86		Range .07-1.4	Range .43-1.30	Range .20-1.69	Range .01-.54	Range .01-.03	Range .16-1.09	Range .02-.05	Range 12.40-61.20	Range .18-4.26	Range 15.5-38.0	Range .50-8.0	Range 1.02-3.02
36.	6-23	12.58	3.96	0	.26	.65	.65	.02	.01	.28	.03	16.78	2.72	17.4	.26	2.04
37.	6-43	2.22	4.06	0	.45	.61	1.35	.05	.04	.65	.04	23.0	2.76	22.0	.74	.60
38.	5-25	.31	3.04	.01	.11	.90	.50	.01	.02	0	.03	4.20	.41	.83	.18	.28
	5-26	1.08	23.4	.09	.14	1.1	.12	.02	.02	.21	.05	5.50	5.94	1.30	1.15	1.12
		$\bar{x}$=.70	$\bar{x}$=13.22	$\bar{x}$=.05	$\bar{x}$=.13	$\bar{x}$=1.0	$\bar{x}$=.31	$\bar{x}$=.02	$\bar{x}$=.02	$\bar{x}$=.11	$\bar{x}$=.04	$\bar{x}$=4.85	$\bar{x}$=3.18	$\bar{x}$=1.07	$\bar{x}$=.67	$\bar{x}$=.70
		s=.55	s=14.4	s=.06	s=.02	s=.13	s=.27	s=.01	s=0	s=.15	s=.01	s=.92	s=3.91	s=.33	s=.69	s=.59
		Range .31-1.08	Range 3.04-32.4	Range 0.1-.09	Range .11-.14	Range .90-1.1	Range .12-.50	Range .01-.02	Range .02	Range 0-.21	Range .03-.05	Range 4.2-5.5	Range .41-5.94	Range .83-1.30	Range .18-1.15	Range .28-1.12
39.	6-22	1.29	11.56	0	.67	.47	.15	.04	.11	.08	.04	20.0	21.8	19.4	.40	15.7
	6-24	1.38	3.76	0	.35	.65	3.0	.03	.61	2.4	.05	19.52	1.05	22.8	.26	3.74
		$\bar{x}$=1.34	$\bar{x}$=7.66		$\bar{x}$=.51	$\bar{x}$=.56	$\bar{x}$=1.58	$\bar{x}$=.04	$\bar{x}$=.07	$\bar{x}$=1.26	$\bar{x}$=.05	$\bar{x}$=19.76	$\bar{x}$=11.43	$\bar{x}$= 21.1	$\bar{x}$=.33	$\bar{x}$=9.72
		s=.06	s=5.52		s=.23	s=.13	s=2.01	s=.01	s=.07	s=1.66	s=.002	s=.34	s=14.67	s= 2.4	s=.10	s=8.46
		Range 1.29-1.38	Range 3.76-11.56		Range .35-.67	Range .47-.65	Range .15-3.0	Range .03-.04	Range .11-.61	Range .08-2.4	Range .04-.05	Range 19.52-20.0	Range 1.05-21.8	Range 19.4-22.8	Range .26-.40	Range 3.74-15.7

Table 5. (continued)

Problem Area Group	Sample Number	ppm														
		B	Pb	As	Se	Al	Ni	Mo	Cd	Co	Cr	Sr	Zn	Fe	Mn	Cu
40.	6-27	1.66	7.88	0	.29	.68	.21	.03	.02	.15	.03	19.76	1.38	32.8	1.05	4.04
	6-29	1.56	36.8	0	.25	2.84	.14	.08	.03	.15	.03	1.75	2.18	33.4	1.02	3.80
	6-35	1.33	2.3	0	.28	.79	.07	.03	.02	.03	.04	12.90	.64	35.2	.65	2.98
	6-36	1.42	2.78	0	.27	.78	.08	.04	.03	.04	.03	12.98	4.26	23.8	.49	.93
		$\bar{x}$=1.5	$\bar{x}$=12.44		$\bar{x}$=.27	$\bar{x}$=1.28	$\bar{x}$=.13	$\bar{x}$=.05	$\bar{x}$=.03	$\bar{x}$=.10	$\bar{x}$=.03	$\bar{x}$ = 11.85	$\bar{x}$=2.12	$\bar{x}$=31.3	$\bar{x}$=.80	$\bar{x}$=2.94
		s=.15	s=16.44		s=.02	s=1.04	s=.06	s=.02	s=.01	s=.07	s=.01	s=7.46	2=1.56	s=5.1	s=.28	s=1.41
		Range 1.33-1.66	Range 2.30-36.8		Range .25-.29	Range .68-2.84	Range .07-.14	Range .03-.08	Range .02-.03	Range .03-.15	Range .03-.04	Range 1.75-19.76	Range .64-4.26	Range 23.8-35.2	Range .49-1.02	Range .93-4.04
41.	6-46	1.99	1.36	0	.28	.46	.49	.12	.04	.25	.03	43.6	2.24	42.4	2.98	5.88
	6-47	2.36	10.26	0	.22	.48	.46	.05	.02	.44	.03	40.4	2.10	45.2	2.60	7.04
		$\bar{x}$=2.18	$\bar{x}$=5.81		$\bar{x}$=.25	$\bar{x}$=.48	$\bar{x}$=.48	$\bar{x}$=.09	$\bar{x}$=.04	$\bar{x}$=.35	$\bar{x}$=.03	$\bar{x}$=42.0	$\bar{x}$=2.17	$\bar{x}$=43.8	$\bar{x}$=2.79	$\bar{x}$=6.46
		s=.26	s=6.29		s=.04	s=.02	s=.02	s=.05	s=.01	s=.13	s=0	s=2.26	s=.10	s=1.98	s=.27	s=.82
		Range 1.99-2.36	Range 1.36-10.26		Range .22-.28	Range .46-.48	Range .46-.49	Range .05-.12	Range .02-.04	Range .25-.44	Range .03	Range 40.4-43.6	Range 2.10-2.24	Range 42.4-45.2	Range 2.60-2.98	Range 5.88-7.04
42.	6-15	1.34	2.34	.716	1.144	36.8	9.96	.108	.172	5.46	.104	40.2	30.0	210.0	.86	6.26

Geochemical Evaluation of Selected Elements on Selected Samples on the Basis of Total Concentrations

In the introduction to this section of the report, reasons were presented for conducting the primary geochemical evaluation on the basis of extractable instead of total concentrations of important elements. Although we feel the rationale and approach used is justified and appropriate, we recognize also that data on total concentration can be of some value. Although, as has been previously stated, total concentration data is of little value for defining the "state" of the geochemical system, extractable chemical data does not indicate what chemical changes might occur, if in fact, conditions were such that geochemical changes could take place. Although, as indicated earlier, we feel that significant changes are unlikely to occur, and/or if they do will occur very slowly, we felt it important to investigate the total concentration of selected elements in selected materials.

Our major limitation in this portion of the study was that lack of material prevented us from selecting samples representative of the various materials studied.

In addition to looking at these data on the basis of total concentration, we were interested in the relationship between total vs. extractable. Thus, both total and extractable levels of the elements considered in this portion of the study are shown in Table 6.

Following is an assessment of the geochemical data on the basis of total concentration for the elements and materials studied.

Total Iron

Total Fe levels range from .03 to 4.27 percent. The mean concentration for soils as reported by Bowen[1] is 3.8 percent. It appears that the total

Fe concentration is at or well below the mean concentration of most soils. It is interesting to note that even though the total concentration of Fe is low in a number of materials, extractable levels appear to indicate that plant available Fe is adequate in most materials.

Total Arsenic

Total As ranged from 0.7 to 13.2 ppm. Bowen reports ranges for all soils to be 1.0 to 5.0 ppm with the mean being 6.0 ppm. Four of twenty samples analyzed were above this mean. It appears that As levels are sufficiently high in these samples to warrant careful consideration.

Total Selinium

Total Se levels ranged from .06 to .98 ppm. Bowen reports ranges of .01 to 2.0 ppm with a mean of .20 for Se in most soils. A number of samples contained Se levels higher than this mean. The plant tissue analyses data reported later indicates that Se levels were abnormally high in plants grown on some materials.

Total Cadmium

Total Cd levels were all below our detection limit of 1.0 ppm. Bowen reports ranges of .01 to 7.0 ppm with a mean of 0.06 for Cd in most soils. Since our detection limit was above this level, we do not know how close to this means the concentrations of Cd are. However, the <1.0 ppm level appears well below any level of concern.

Total Copper

Total Cu levels range from 3 to 24 ppm. These are well below or about equal to the mean of 20 ppm Cu for most soils as reported by Bowen. One

[1]Bowen, J. J. M. 1966. Trace Elements in Biochemistry. Academic Press, New York, N. Y. 241 p.

concern might be that on materials with Cu levels < 5 ppm, Mo may become a problem if the Mo levels are high. However, the data on Mo does not indicate Mo to be above normal.

Total Nickel

Total Ni levels range from 1 to 31 ppm. Total Ni levels appear to be much higher than normal (>10-20 ppm.) in a number of samples. Nickel could be considered a problem in some materials if the extractable levels are high (>5.0 ppm).

Total Zinc

Total zinc levels range from 3 to 100 ppm. This compared to a mean concentration of 50 ppm as reported by Bowen for most soils (range 10-300) indicates that the zinc levels of some materials are higher than normally found.

Total Molybdenum

Bowen reports ranges of 0.2 to 5.0 ppm and a mean of 1.0 ppm Mo for most soils. Since our detection limit is <3.0 ppm for total Mo we do not know precisely where the materials tested fit relative to the levels reported by Bowen. However, a level of 3.0 ppm is not excessive and well within normal ranges.

Total Manganese

Total Mn levels range from 5 to 605 ppm and are well below the mean of 850 ppm for most soils as reported by Bowen. Mn deficiencies rather than toxicities appear to be more likely.

Total Boron (Hot water extractable)

Total B levels range from .10 to 2.06 ppm and appear to be well below the critical level of 5.0 ppm.

Table 6. Geochemical Data for Total and Extractable As, Se, Cd, Cu, Ni, Zn, Mo, Mn and Fe on Selected Materials.

Sample No.	Total Fe %	Ext.	Total As ppm	Ext. *	Total Se ppm	Ext.	Total Cd ppm	Ext.	Total Cu	Ext.	Total Ni	Ext.	Total Zn	Ext.	Total Mo	Ext.	Total Mn	Ext.	Total B **	Ext.
3-4	.32	9.1	5.4	ND	.31	.08	<1	.01	4	.27	3	.11	8	.72	<3	.02	41	2.8	.10	.1
3-5	2.35	24.6	6.8	ND	.79	.23	<1	.01	18	.55	29	.03	94	2.4	<3	.03	256	2.0	2.1	1.3
3-9	2.52	28.2	13.2	ND	.98	.16	<1	.02	20	1.5	31	.7	95	3.3	<3	.03	233	1.9	2.0	1.4
3-10	2.42	29.6	6.3	ND	.87	.21	<1	.01	20	2.3	31	1.5	100	4.8	<3	.04	217	1.6	2.1	1.3
3-16	2.34	23.6	7.7	ND	.54	.12	<1	.03	16	.6	24	1.1	84	5.7	<3	.07	184	2.2	1.0	1.0
3-19	1.64	5.2	6.0	ND	.63	.26	<1	.02	13	.5	22	.5	70	.74	<3	.03	162	2.5	.6	.6
4-13	.52	17.4	1.4	ND	.14	.11	<1	.02	4	.25	3	.14	13	.56	<3	.02	93	5.7	.3	.3
5-9	.76	2.9	2.7	ND	.20	.15	<1	.01	9	1.1	8	.04	32	.99	<3	.02	31	.21	.4	.32
5-20	2.12	37.2	4.6	ND	.37	.33	<1	.03	11	.38	13	.41	60	2.9	<3	.05	262	4.3	.3	.3
5-23	1.54	6.0	1.3	ND	.30	.25	<1	.01	5	.5	6	.07	41	.49	<3	.02	198	1.9	.13	.12
5-25	.03	.8	.7	ND	.24	.11	<1	.02	3	.2	1	.5	3	.41	<3	.02	5	.18	.4	.31
5-26	.09	1.3	.9	ND	.06	.1	<1	.02	6	1.1	2	.12	17	5.9	<3	.03	12	1.2	1.4	1.0
5-28	.36	22.0	1.3	ND	.08	.1	<1	.02	6	.6	5	1.2	31	8.4	<3	.01	14	2.6	.2	.14
6-19	1.54	17.2	1.2	ND	.53	.36	<1	.05	22	.76	14	.20	96	4.3	<3	.06	300	3.9	.9	.8
6-21	.20	9.2	.9	ND	.24	.21	<1	.01	9	1.6	3	.07	21	1.1	<3	.02	12	.22	.8	.5
6-57	.82		2.1	ND	.16	.24	<1	.02	4	.28	6	.20	17	.57	<3	.03	276	4.5	.18	.17

*ND = Not Determined

**Total B = Hot Water Soluble Boron

A comparison of the total concentration vs. extractable levels for those elements studied indicates, as we would expect, that extractable levels are not always indicative of total concentration. Although there is a trend that as the total concentration increases, extractable levels increase. The degree of increase or decrease in extractable as a function of total concentration varies considerably for most elements.

In summary, the total concentration data would appear to indicate that Ni, As and Se are present in sufficient amounts in some materials to warrant careful consideration of the use of these materials. In the case of Ni, the extractable levels are quite low and plant analyses data reported later would suggest that Ni uptake is quite low in materials where extractable Ni is similar to that reported in Table 6. Thus it appears that Ni would become a problem only if the biogeochemical environment changed the material to an acid system. As long as it remains alkaline, Ni availability to plants and mobility in the environment will be low. Since there is no readily available method for determining "extractable" As, it is difficult to assess the significance of the various concentrations found. In addition, the plant analyses data reported later is of little value because of the problem we encountered with detection limits for this element. The relationship of Se to plant response is discussed later under the greenhouse section of this report. However, it does appear that Se levels are sufficiently high to warrant concern and it appears that some materials contain a sizeable "pool" of this element.

Finally, it appears that both total concentration and extractable chemical data are needed to assess the geochemical nature of materials. However, the authors opinion is still that primary emphasis should be placed on extractable with secondary emphasis on total concentration analyses.

PART IV

GREENHOUSE GROWTH STUDIES AND PLANT TISSUE ANALYSES

Greenhouse growth studies and accompanying plant tissue analyses were carried out to verify the performance and/or plant growth characteristics predicted from laboratory characterization data of the overburden materials studied.

Due to insufficient amounts of materials, we were unable to conduct greenhouse studies on all materials. Considering that a minimum of 150 grams of material was needed for laboratory analyses and that the amounts per sample received ranged from 100 to 300 grams, it was necessary to select first, on the basis of single samples where sufficient materials were available and second, group or combine materials with similar properties.

Although additional materials from Bore Holes 3, 4, 5, and 6 were received, the samples represented different depth increments of the core than the samples which were received initially. Thus we were unable to use these as supplemental material for making up greenhouse treatments.

Given the situation described above, we developed the greenhouse study on the basis of selecting individual samples and/or grouping samples to reflect what appeared to be the major factors controlling the opportunities and/or constraints that materials offered as media for plant growth. Namely, materials which appeared to be well suited as plant growth media, and materials which were affected by either one or a combination of salinity and sodium, and materials which were characterized by low pH.

The greenhouse pot identification number, materials associated with each pot and the mean yield of western wheatgrass obtained on each material

are shown in Table 7. Plant tissue analyses data are shown in Table 8.

The results of the combined greenhouse and plant tissue analyses study appear to indicate the following:

1. Greenhouse pot 23 which represented the low pH materials produced an intermediate yield of western wheatgrass. More important consideration however, is that the Ni content in the plant tissue was 10 to 20 fold greater than the amounts found in plants grown on most of the other materials. The Se level was also elevated. Also, the Mg to Ca ratio was very high. It appears that the elevated Se level is more directly related to the soluble salts and not low pH. Not only would we expect this to be true, but elevated Se levels in plants grown on some of the other materials also seemed to be associated with high salinity levels.
2. Pots 1, 5, and 8 represented materials, which other than fertility, showed no apparent limiting features to plant growth. Correlation between soil characterization data, plant yield and tissue analyses are very good in that there are no identifiable problems other than possible fertility deficiencies, which for N, P, and K were corrected in the greenhouse, and the yields of western wheatgrass reflect these relationships.
3. The greenhouse data proved to be critical for assessing plant growth potential on materials identified as Pots 2, 3, 4, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, and 29. Growth of western wheatgrass ranged from none to .26 gm/pot. The common feature among all these materials, in addition to low fertility, is texture and a very low Cation Exchange Capacity. The coarse

Table 7. Yield Data from Greenhouse Growth Study.

Greenhouse Pot No.	Materials Comprising Greenhouse Treatment	$\bar{x}$ Yield
		gm./pot
1	5-9	.89
2	6-1 6-5	*
3	5-26	*
4	5-25	*
5	5-1	1.72
6	3-5 6-19	.07
7	6-10 6-20	.54
8	5-10 5-18	1.20
9	5-27	1.31
10	5-4 5-5 6-4	.17
11	6-17 6-18 5-20	.26
12	6-51 4-20 4-15 4-14	--
13	4-10 4-2 5-17 5-16	.02
14	5-28	.12
15	6-7	*
16	6-53	.07

Table 7. (continued)

Greenhouse Pot No.	Materials Comprising Greenhouse Treatment	$\bar{x}$ Yield
17	3-1 3-2 3-3	*
18	3-4 4-13	*
19	6-21	*
20	5-12 6-11	.20
21	6-57	.16
22	5-22 5-23	*
*23	6-12 6-13 6-16	.53
24	3-19 6-23	.33
25	4-7 6-45	.23
26	3-17A 3-17B 3-18	.33
27	6-46 6-47	.30
28	3-9 3-10 3-16	.11
29	4-3 4-19 6-32 6-54	*

*No growth reported. Plants either died upon emergence or shortly thereafter.

Table 8. Plant Analyses Data.

Sample No.	Total Concentration*												
	%				ppm							%	ppm
	Ca	Mg	Na	P	Fe	Mn	Cu	Zn	Cd	As	Se	S	Ni
8	.32	.33	.04	.33	72	26	8	37	<.3	<.5	.11	.18	2.6
1	.51	.33	.02	.35	72	39	9	20	<.3	<.6	.38	.29	.9
5	.21	.48	.17	.30	64	14	8	18	<.2	<.5	.07	.18	1.0
6	1.02	.53	.67	.12	129	67	10	26	<1.0	<1.6	1.01	.2	1.1
7	.81	.47	.25	.25	70	65	6	30	<.4	<.7	3.26	.19	1.6
9	.29	.23	.07	.23	61	32	5	46	<.2	<.5	.40	.19	.6
10	.99	.30	.10	.18	87	61	11	21	<.8	<1.5	.70	.18	1.2
11	1.02	.63	.20	.18	70	38	8	18	<.5	<1.2	.46	.21	1.8
13	1.14	.59	.20	.17	173	98	12	31	<.8	<1.6	.13	.23	1.7
14	.43	.21	.37	.42	113	74	13	40	<.5	<1.1	.08	.25	10.8
16	1.58	1.35	.25	.22	2705	187	12	33	<2.5	<5.0	.22	.32	<2.5
20	1.15	.95	.27	.13	116	66	8	27	<1.0	<1.9	.85	.15	1.4
21	2.61	.48	.07	.18	2058	143	9	19	<1.1	<2.3	.20	.67	3.8
23	.38	.78	.47	.24	81	10	11	54	.5	<.7	2.2	.36	27.0
24	.47	.31	.69	.18	117	69	9	45	<.4	<.7	.68	.16	1.9
25	.42	.24	2.90	.14	115	84	9	29	<.7	<1.5	5.68	.55	2.6
26	.24	.19	1.04	.19	126	72	5	23	<.4	<.7	.48	.37	.9
27	.26	.10	1.10	.20	87	67	11	28	<.4	<.8	3.2	.20	.8
28	.58	.38	6.69	.10	225	42	7	28	<.6	<1.1	1.58	ISS	2.7

*Data are based on an average of 2 replications.

texture indicates a very low available water holding capacity and the extremely low cation exchange capacity indicates a very low overall inherent fertility or productivity potential. Although the plant tissue analyses indicates that the levels of essential nutrients such as P, S, Fe, Mn, Cu, Zn, Ca, and Mg are above critically deficient levels, they are in many cases borderline. Also, we have to remember that the plant tissue analyses are not good indicators of plant nutrition because of the stresses associated with restricted growth.

In general, we felt that even though these materials were coarse textured and very low in inherent fertility potential, the growth response should have been better, considering that N, P, and K were added and the plants were watered daily. On the other hand, with the high evaporation potential associated with growth of plants in the greenhouse, it is possible that severe moisture stress occurred and the growth of the crop was affected accordingly. We have concluded that the soil-plant-moisture relationship aggravated by the very low overall fertility status were the critical factors affecting yields on these materials.

4. It appears that good correlation was obtained between plant growth, soil characterization data and plant tissue analyses on materials represented by Pots 6, 7, 24, 25, 26, 27 and 28. These materials are affected by salinity and sodium, either alone or in combination. The yields obtained are intermediate between those obtained on the coarse textured, low fertility materials and the materials on which the best growth occurred. This

suggests that both sodium and salinity, either alone or in combination did restrict yields. In addition, it appears that as the salinity in the material increases, Se uptake by plants increases. This same relationship is true relative to Na.

5. The results obtained on materials represented by Pot 20 are not easy to interpret. We would have predicted the growth response to be equal to that obtained on materials in Pots 1, 5, 8, and 9. However, this was not the case. Except for the borderline copper level as indicated by the plant analyses, there seems to be no other apparent reason for the poor performance of western wheatgrass on this material.
6. An interesting response was obtained on the material represented by Pot 19. We would have expected an intermediate growth response similar to what was obtained on the materials having a potential sodium problem. However, no growth was obtained. This material is classed as being a loam texture. However, the sand, salt, and clay ratio is near a sandy loam. Also, the silt to clay ratio is higher than typical for a loam. The cation exchange capacity of the soil is quite low indicating that the type of clay present also has a low cation exchange capacity. It appears that the sodium level in addition to a low inherent fertility potential contributed to the lack of growth.

In summary, except for the materials represented by Pots 19 and 20, the greenhouse and plant analyses data emerged as being a very useful tool for supporting the interpretations made base on the chemical and physical nature of the overburden materials.

PART V

ADDITIONAL LABORATORY CHARACTERIZATION BORE HOLE 2 MATERIALS

In addition to laboratory characterization of the materials submitted from Bore Holes 3, 4, 5, and 6, some additional analyses were conducted on samples received December 1, 1979 from Bore Hole No. 2. Analyses were restricted to those shown as we received fifty to 100 grams of total samples. Since texture could be described qualitatively from the geologic logs, it was determined that based on the limited amount of sample available, salinity and pH analyses could provide the most useful interpretive data.

Based on the electrical conductivity and pH analyses shown in Table 6, the following general interpretations can be made for materials from Bore Hole No. 2.

1. Materials 2-5 and 2-14 are questionable to unsuitable because of salinity levels.
2. Materials 2-5 and 2-18 should be considered unsuitable because of low pH.
3. Material 2-12 is questionable because of moderately low pH.
4. Materials 2-1, 2-24, 2-31, and 2-35 are flagged as problem materials because of a potential sodium problem as indicated by the pH.

If the textures of any of the materials are determined to be either sand, loamy sand, clay, silty clay or sandy clay, the materials should be considered as being unsuitable as plant growth media.

In addition to the Bore Hole No. 2 materials, seven samples labeled as 10-1 through 10-7 were received on the same date. We assume that these materials are from Bore Hole No. 1. The same analyses were performed as

those performed on materials from Bore Hole No. 2. The data are shown in Table 10 and the samples are labeled as received in the laboratory. Field records should be checked to correctly identify these materials.

The data shown in Table 10 indicates that except for samples 10-2 and 10-3, which have a very low pH, the other materials exhibit no undesirable characteristics which can be identified from these analyses.

Table 9. Electrical Conductivity and pH Analyses of Materials from Bore Hole 2.

Sample Number	pH	Elect. Cond.
2 - 1	8.4	0.3
2 - 3	7.3	1.3
2 - 4	6.6	3.0
2 - 5	2.7	7.8
2 - 7	6.6	2.0
2 - 9	7.6	2.1
2 - 10	7.4	1.6
2 - 11	7.6	2.4
2 - 12	5.4	2.2
2 - 14	7.3	6.9
2 - 16	6.7	3.7
2 - 18	3.5	3.7
2 - 19	7.5	1.0
2 - 20	7.5	0.6
2 - 21	7.0	0.7
2 - 23	6.0	2.9
2 - 24	8.9	1.0
2 - 26	8.0	1.3
2 - 27	7.5	2.2
2 - 28	7.7	1.3
2 - 29	6.7	1.9
2 - 30	7.5	2.0
2 - 31	8.5	1.4
2 - 32	7.1	0.8
2 - 33	8.0	1.4
2 - 35	8.5	0.2
2 - 37	7.5	1.9
2 - 39	7.3	2.3
2 - 41	6.9	3.4

Table 10. Electrical Conductivity and pH Analyses of Materials from Bore Hole 1.

Sample Number	pH	Elect. Cond.
10 - 1	7.3	2.6
10 - 2	3.6	3.5
10 - 3	3.5	3.8
10 - 4	7.2	2.4
10 - 5	6.9	1.5
10 - 6	8.1	1.1
10 - 7	7.6	1.2

PART VI

ADDITIONAL SPECIES EVALUATION

Seeds of Kochia prostrata; Atriplex canescens (fourwing salt brush); Sphaerolcea coscinia (scarlet globemallow); and Sporobolus airoides (alkali sacaton); were tested in the greenhouse on materials on which western wheatgrass performance was either good, poor, or none.

These species were planted on November 8, 1978 after harvest of the western wheatgrass. All western wheatgrass roots were removed from each pot, the materials were repotted, fertilized with nitrogen and replanted.

The results of this portion of the study are shown in Table 11. The results of the study were disappointing in that we expected equal or better performance from all species on all materials on which the western wheatgrass performed well and an acceptable performance from alkali sacaton and fourwing salt brush on materials in pots 25, 26, 27, and 28 which are highly alkaline and/or salt affected. Only alkali sacaton performed as expected.

Seed source was that collected from native plants in the field. We do not have any data on seed viability and/or germination. This factor must be considered in evaluating the data. On the other hand, the same conditions i.e., very low water holding capacity or droughtiness and apparent very low inherent fertility status of materials in pots 13, 15, 17, and 29 may have been as limiting to growth of these species as they were to western wheatgrass. And high sodium and/or salinity may have restricted germination of the globemallow, fourwing salt brush and Kochia on materials in pots 26, 27, and 28 respectively. However, there is no evidence other than poor seed viability or possibly the moderately low pH associated with the material in pot 23 for explaining the poor performance of species grown

on materials in pots 5, 7, and 23.

Seed germination tests are being conducted by the Colorado State Seed Testing Laboratory and those results will be submitted in the form of an addendum to this report as soon as the results are obtained.

Table 11. Growth Results Obtained in Greenhouse from Kochia, Fourwing Salt brush, Scarlet Globemallow and Alkali Sacaton.

Greenhouse Pot No.	Species Grown	Western Wheatgrass Performance	Other Native Species Performance
8	Alkali sacaton	Good	Good
5	Globemallow	Good	Poor-germinated after 6 weeks
7	Fourwing salt brush	Good	No germination or growth
23	Kochia	Good	No germination or growth
25	Alkali sacaton	Poor	Poor germination and growth
26	Globemallow	Poor	No germination or growth
27	Fourwing salt brush	Poor	No germination or growth
28	Kochia	Poor	No germination or growth
29	Fourwing salt brush	No growth	No germination or growth
13	Globemallow	No growth	No germination or growth
17	Kochia	No growth	No germination or growth
15	Alkali sacaton	No growth	No germination or growth

PART VII

MINERALOGICAL ANALYSES

The greenhouse studies suggested that our efforts in a mineralogical study could best be directed toward assessing further the relationship between low cation exchange capacity and poor growth obtained on the coarse textured materials. In addition, it was obvious from the laboratory characterization data that most of the materials were either very coarse textured-high sand and most likely a high quartz content, or were fine textured with a high clay content. Thus, it appeared that a mineralogical investigation of the clay fraction was more appropriate. Thus, the decision was made to conduct the mineralogical analyses on the clay fraction of materials from selected greenhouse pots to better determine the fertility potential of materials on which western wheatgrass performed poorly. In addition, it was felt that the analyses could aid in identifying the nature of the geologic environment. The results of the mineralogical analyses are shown in Table 12. The results in Table 12 show that kaolinite is the dominant mineral present. This explains the very low cation exchange capacity associated with these materials. In addition, there are very low amounts of weatherable minerals that act as a sink for needed plant nutrients. These results confirm our suspicion regarding the inherent low fertility potential associated with the coarse textured materials. Not only are the materials characterized by having very low available moisture capacity but also they have a very low nutrient supplying capacity.

The presence of large amounts of kaolinite suggests that these materials were derived from an area where the weathering intensity and leaching potential were quite high. The mineral suite of the clay fraction

is very atypical of what we find in most soils in semi-arid regions where typically, the clay fraction is dominated by minerals of the smectite group.

Table 12. Selected Mineralogy of the Clay Size Fraction of Selected Samples.

Mineral Group	Greenhouse Sample Number #3	#4	#18	#19
Smectite	Trace - 5%	0-5%	0-5%	0-5%
Mica	9%	2-5%	5%	2.5-5%
Kaolinite	81-91%	79-87%	77-82%	69-76%
Quartz	Trace - 5%	11%	13%	21%

Detection limit @ 5%

GENERAL SUMMARY

The results of the greenhouse and laboratory characterization work carried out in this study indicate the following:

1. Extractable geochemical data are very useful for evaluating those elements which are potentially more mobile in materials with low pH, particularly for pH <5.0.

   Further, it appears that the "extractable" geochemical data correlates better with yield and plant uptake response than does the "total concentration" data. Thus, it is a better tool for evaluating potential problems.

2. Current thought relative to interpreting salinity and sodium problems appears to be that materials classed as moderate salinity and/or sodium are in most cases acceptable. The results of the greenhouse growth studies indicate that salinity and/or sodium which occur at these levels are, in fact, limiting to plant growth and we should be cautious in using them as plant growth media.

3. Coarse textured-sandy materials exhibiting very low available water holding capacity and inherent low fertility potential appear to be highly unsuitable for use as plant growth media.

4. There is considerable interest in mixing highly carbonaceous and often times acid materials with other geologic materials for improving water holding capacity and overall plant growth suitability. Based on the mineralogical investigations, we would be very concerned about the appropriateness of this procedure, particularly if the mixture included the more sandy overburden materials. The high abundance of kaolinite type

clays suggests that these materials have a very low buffering capacity against acidity. Thus, if moderate to strongly acid materials were mixed with other materials, there remains the possibility of the media to remain acid. This situation could be further aggravated if pyritic type materials were present. These materials would tend to increase acidity levels by oxidizing pyrites to form sulfuric acid which is a very strong acid. The potential, however, of this occurring is dependent on the exact nature and ratio of materials to be mixed. More importantly, it must be recognized that mixing should not be done indiscriminantly.

5. Elevated levels of Se and B in plants appear to be associated with higher salinity.
6. In general, it appears that a large number of materials are characterized by properties which limit their use either as plant growth media and/or will require special consideration from an environmental quality point of view.

- APPENDIX -

Appendix Table 1. Laboratory Characterization Data to Determine Plant Growth Suitability.

Sample Number	Sat. pH	Elec. Cond.	% ESP	% O.M.	CEC	meq/l Saturated Ext. Ca	Mg	Na	K	NH_4 K	OAC Ext. ppm Ca	Mg	Na	DTPA Ext. ppm Zn	Fe	Cu	Mn	Particle Size % S	% Si	% C	Text. Class	Depth
B. H. 3																						
1	6.8	3.9	2.05	0.4	0.3	31.4	6.5	4.6	0.05	11	.0678	38	40	2.30	31.4	0.84	5.11	88	9	3	LS	202'3"-202'9"
2	7.2	3.6	2.90	0.4	0.2	36.0	8.0	6.5	0.79	14	943	42	53	1.65	18.9	0.70	5.42	84	11	5	LS	191'11"-191'7"
3	7.3	3.5	2.08	0.6	0.3	36.9	6.4	4.3	0.54	10	1180	38	46	0.74	24.6	0.18	5.80	85	10	5	LS	181'2"-181'9"
4	7.7	3.4	2.9	0.4	0.3	33.2	7.6	6.2	0.54	18	2170	36	41	0.72	9.1	0.27	2.84	86	9	5	LS	182'4"-182'10"
5	7.9	2.7	15.3	1.4	9.0	4.2	3.7	20.2	0.61	150	3620	304	383	1.28	24.6	0.55	2.00	37	28	35	SiCL	161'11"-162'6"
7	7.9	6.4	22.8	1.4	8.0	9.7	7.6	49.5	1.04	157	4100	266	670	1.61	22.8	0.89	1.64	47	22	31	SiCL	152'3"-152'10"
8	8.0	5.2	33.1	1.5	7.8	3.1	1.9	45.6	0.59	192	3990	178	1090	.95	23.8	0.23	1.43	51	22	27	SCL	142'3"-142'8"
9	8.2	7.8	44.0	1.5	10.5	3.4	2.1	75.1	0.71	190	2880	178	1650	3.38	28.2	1.52	1.90	21	34	45	C	132'3"-132'9"
10	8.1	7.2	43.0	1.3	13.1	3.2	2.0	69.4	0.64	252	3855	185	2000	4.84	29.6	2.34	1.61	11	38	51	C	127'3"-122'9"
11	8.2	6.9	40.3	1.7	14.0	3.8	2.1	66.0	0.64	256	3740	171	2080	4.20	26.4	0.91	1.38	21	29	50	C	112'3"-112'9"
12	8.4	5.8	38.8	1.1	15.8	2.5	1.8	53.3	0.46	282	2870	380	2390	4.76	25.2	1.13	1.50	17	32	51	C	102'3"-102'9"
13	8.3	9.0	38.6	1.2	16.8	6.5	3.5	81.2	0.74	285	3860	199	2940	4.50	27.6	0.70	1.51	13	36	51	C	92'3"-92'9"
14	8.5	6.7	43.4	1.8	17.2	2.4	1.3	60.3	0.44	302	3860	190	3030	4.14	29.0	0.32	1.53	22	29	49	C	82'3"-82'9"
15	8.4	6.7	46.3	1.4	17.8	2.0	1.2	61.6	0.41	309	3830	228	3480	5.92	27.8	0.75	1.54	18	32	50	C	72'3"-72'9"
16	8.4	9.3	48.1	1.4	18.9	3.2	2.9	92.4	0.54	287	3830	372	3820	5.72	23.6	0.64	2.24	17	33	50	C	62'3"-62'9"
17	8.1	15.5	37.7	1.1	17.0	24.6	15.3	155.	0.99	213	5720	440	2990	0.97	7.6	0.41	1.43	18	42	40	SiC/SiCL	52'3"-52'9"
18	8.4	11.6	36.01	1.3	15.4	9.6	10.2	102.	0.82	214	3900	513	2260	1.72	9.4	0.41	1.41	23	44	33	CL	42'3"-43'9"
19	8.4	4.3	21.90	0.7	11.8	3.8	5.9	35.2	0.51	174	3680	699	849	0.74	5.24	0.47	2.52	34	35	31	CL	33'3"-33'7"
20	8.1	10.4	16.9	0.9	10.9	27.6	38.4	65.5	1.10	158	5375	751	814	0.51	9.95	0.42	2.00	33	32	35	CL	23'8"-24'
178	8.1	17.9	40.6	1.1	18.1	25.4	16.4	180.	0.94	220	7410	470	3430	1.24	5.28	0.34	2.38	23	22	45	C	54'9"-55'9"
B. H. 4																						
1	8.0	5.5	5.6	0.6	1.0	36.5	33.8	18.6	1.10	27	1550	242	89	0.8	31.6	0.21	5.42	76	17	7	SL	193'8"-194'
2	8.2	3.6	1.9	0.8	0.5	31.1	18.2	4.0	0.69	17	3320	92	25	0.57	13.7	0.17	2.96	83	13	4	LS	175'6"-176'
3	8.4	1.1	5.3	0.3	0.4	3.2	3.3	5.2	0.36	10	2830	54	35	1.82	13.4	1.29	5.02	86	12	2	S/LS	164'3"-164'9"
5	7.5	6.0	12.1	3.5	3.6	26.0	24.4	38.1	1.20	67	498	176	235	1.00	46.4	0.51	3.30	54	34	12	SL	149'-149'5"
6	8.2	4.8	19.1	1.9	4.3	8.8	8.6	39.1	0.89	101	1320	227	406	3.98	13.9	0.65	3.22	64	19	17	SL	143'143'6"
7	8.5	2.1	32.3	2.0	9.7	0.6	0.6	20.5	0.31	211	2540	374	897	2.54	38.0	1.02	5.30	40	27	33	CL	135'3"-135'9"
8	7.7	4.7	5.1	0.8	0.7	34.6	18.6	14.7	0.97	20	2530	157	124	1.26	17.7	0.18	6.90	79	13	8	LS	125'3"-125'9"
9	7.9	6.0	27.1	2.9	8.5	6.4	8.4	57.3	1.07	196	963	543	733	4.16	38.0	0.81	3.20	34	37	29	CL	131'-131'6"
10	8.0	2.4	9.01	0.3	0.8	8.4	4.8	13.8	0.89	46	302	53	123	3.47	3.2	0.22	2.93	78	12	10	SL	115'4"-115'10"
11	6.9	3.2	21.5	4.6	4.6	2.8	4.8	29.6	0.46	73	252	203	327	1.41	43.2	1.23	0.92	64	23	13	SL	108'6'-109'1"
12	2.3	17.8	.91	5.8	1.6	37.0	31.9	0.9	0.05	10	1120	119	9	15.0	1940	0.09	14.20	81	9	10	LS	92'2"-93'6"
13	6.9	3.1	1.75	1.6	0.4	34.1	7.0	3.0	0.61	14	261	41	24	0.56	17.4	0.25	5.78	88	9	3	LS	84'5"-84'10"
14	6.0	3.7	2.05	1.1	1.7	23.4	29.3	4.9	1.07	43	503	243	41	2.32	27.2	0.46	3.50	74	15	11	SL	74'8"-75'2"
15	6.9	1.9	3.23	0.4	1.6	7.2	10.4	4.9	1.00	50	288	175	39	4.90	34.6	0.53	1.85	60	30	10	SL	64'8"-65'1"
16	4.6	5.5	4.2	2.6	9.3	25.9	37.3	12.3	2.22	210	923	569	125	12.50	7.04	2.80	1.00	31	43	26	L	56'-56'10"
17	6.8	4.6	4.9	1.4	19.9	24.6	27.3	14.0	1.86	407	2450	1250	243	16.00	9.96	2.52	0.34	20	18	62	C	5'8"-52'2"

Appendix Table 1 (continued)

Sample Number	Sat. pH	Elec. Cond.	ESP	O.M.	CEC	meq/l Saturated Ext. Ca	Mg	Na	K	NH_4 K	OAC Ext. ppm Ca	Mg	Na	DTPA Ext. ppm Zn	Fe	Cu	Mn	Particle Size % S	% Si	% C	Text. Class	Depth
B. H 4 (continued)																						
19	7.1	2.8	2.05	0.4	1.0	13.2	16.1	3.9	0.59	27	1950	145	40	7.52	19.1	1.20	2.80	80	10	10	SL	34'3"-34'9"
20	7.1	3.5	2.41	0.6	2.1	13.4	33.4	5.1	1.10	53	382	328	39	5.16	43.2	0.74	2.56	74	15	11	SL	24'3"-24'9"
9B	7.8	8.9	24.4	3.5	8.3	14.8	19.6	76.0	1.53	180	912	537	679	4.22	32.2	0.74	3.42	35	37	28	CL	131'-131'6"
B. H. 5																						
1	7.0	3.9	8.0	0.2	10.9	6.9	24.6	18.5	0.26	55	609	1010	360	0.46	1.6	0.69	0.16	18	49	33	SiCL	13'-13'6"
3	6.5	4.6	78.0	2.4	22.2	11.8	24.6	20.1	0.41	81	2010	1420	389	1.73	53.8	1.78	0.21	24	35	41	C	17'9"-18'6"
4	7.6	0.6	4.03	0.3	2.0	1.8	2.1	2.9	0.19	28	2060	153	34	1.40	3.3	1.09	2.44	63	30	7	SI	35'3"-35'9"
5	7.6	0.9	5.6	0.3	3.5	2.2	2.7	4.9	0.23	45	495	247	42	0.75	1.8	1.06	3.10	58	30	12	SL	43'4"-43'9"
7	7.5	1.5	4.2	0.2	4.7	5.0	5.9	5.2	0.61	98	1350	435	80	2.30	4.3	0.92	2.44	56	30	14	SL	63'4"-63'10"
8A	6.9	1.9	4.0	0.1	16.9	6.6	8.0	5.7	0.66	299	1680	1070	163	2.54	8.7	0.40	0.08	6	17	77	C	67'6"-68'6"
8B	7.0	2.2	3.9	0.2	15.8	8.8	11.1	6.2	0.71	353	1790	1190	189	3.58	7.80	1.92	0.12	18	20	62	C	
9	7.2	1.7	4.5	0.2	7.1	5.9	6.5	5.9	0.83	46	265	149	46	0.99	2.90	1.11	0.21	36	55	9	SiL	73'3"-73'9"
10	6.9	1.2	3.4	0.4	13.8	3.6	5.5	3.6	0.82	338	1090	1160	101	2.84	3.54	2.30	0.43	16	34	50	C	83'2"-83'9"
12	7.4	1.5	2.08	0.4	10.5	6.8	7.3	2.5	1.36	313	1570	724	79	6.24	8.46	4.02	4.72	23	44	33	CL	103'1"-103'6"
13	6.3	4.8	2.9	1.6	18.8	26.7	36.7	8.0	2.98	547	7600	1255	148	14.2	44.0	3.67	8.56	26	17	57	C	112'-112'6"
14A	5.2	4.2	2.08	5.3	12.4	27.6	30.7	5.0	1.94	225	1820	652	94	0.60	67.8	2.04	0.98	58	21	21	SCL	114'6"-115'
14B	5.9	4.4	2.4	5.3	25.3	27.0	32.2	6.2	2.35	567	4570	1730	187	1.94	56.6	3.26	0.88	43	7	50	C	113'4"-113'7"
15	6.8	4.4	1.9	4.9	8.1	29.4	32.6	4.4	1.17	49	3920	615	59	3.64	30.4	1.70	20.80	69	16	15	SL	124'4"-124'10"
16	7.2	4.0	1.4	0.2	1.6	29.0	30.9	3.0	0.87	15	3890	239	38	0.62	19.9	0.48	9.56	78	12	10	SL	127'1"-131'0"
17	7.5	3.4	1.6	0.3	1.3	28.6	20.0	3.1	0.87	17	5200	182	39	0.63	11.6	0.51	6.20	74	14	12	SL	133'2"-133'9"
18	7.0	3.0	7.2	1.9	12.4	7.4	15.0	14.8	1.20	253	934	1130	314	7.84	19.6	2.02	0.58	14	28	58	C	139'9"-140'3"
19	2.5	16.2	6.4	5.2	12.3	26.6	172.	35.4	0.18	10	1680	1110	314	4.02	510	2.90	3.56	56	13	31	SCL	143'3"-143'9"
20	6.4	3.8	3.4	1.3	2.7	19.6	29.4	8.5	0.87	42	3140	315	92	2.98	37.2	0.38	4.32	73	18	9	SL	153'9"-154'3"
22	7.2	1.6	3.7	0.2	0.7	3.6	10.8	5.0	0.26	10	892	174	68	0.57	5.68	0.46	2.56	83	9	8	LS	173'-173'8"
23	7.4	3.6	6.1	0.2	1.1	11.5	31.0	15.9	0.59	13	1770	230	89	0.49	6.05	0.52	1.97	80	11	9	LS	183'0"-183'3"
25	8.1	0.7	15.3	3.3	0.6	0.4	0.3	6.2	0.08	10	76	32	103	0.41	0.83	0.28	0.18	94	6	0	S	217'10"-218'3"
26	8.3	1.2	17.6	0.3	0.5	12.0	21.5	0.9	0.60	10	779	36	106	5.94	1.30	1.12	1.15	89	5	6	S	224'4"-224'10"
27	7.6	1.9	11.1	0.4	32.3	3.2	3.9	12.9	0.46	285	5160	3630	1190	14.50	3.42	3.00	0.80	31	15	54	C	202'9"-203'6"
28	7.4	3.3	12.7	0.6	0.9	31.2	5.8	13.2	0.06	10	699	55	158	8.42	22.0	0.62	2.62	79	13	8	LS	244'1"-244'9"
B. H. 6																						
1	7.4	0.6	9.4	0.2	1.0	0.5	0.6	4.3	0.06	10	83	92	83	0.90	6.94	0.82	1.80	93	4	3	S	8'2"-8'8"
3	7.5	3.5	6.5	0.6	14.2	18.5	11.4	14.2	0.46	111	5140	689	306	1.07	5.56	1.51	2.94	21	42	37	CL	13'5"-13'9"
4	7.5	2.5	5.6	0.5	7.8	8.8	8.9	9.3	0.31	53	3720	475	180	0.47	14.8	0.35	3.52	63	22	15	SL	14'3"-14'6"
5	7.8	0.6	2.4	0.2	0.7	1.9	2.7	1.7	0.07	10	450	128	32	0.34	4.86	0.25	1.00	90	6	4	S	21'4"-21'8"
7	5.2	3.7	1.4	0.2	1.2	27.4	29.1	2.8	0.33	10	1430	190	41	1.67	5.22	1.08	6.22	85	8	7	LS	42'3"-42'9"
8	3.0	15.2	2.4	7.0	31.8	24.8	48.4	6.7	0.54	33	2480	351	112	10.4	61.2	0.36	11.50	76	6	18	SL	51'4"-51'7"
9	2.8	15.2	2.6	6.9	23.6	28.8	63.7	8.5	0.66	21	1230	329	110	8.24	55.2	0.78	9.06	64	4	32	SCL	51'9"-52'3"
10	6.0	3.2	6.8	2.5	13.6	11.2	13.6	13.6	0.92	196	1690	1030	297	3.36	52.2	0.97	1.41	27	30	43	C	56'9"-57'4"
11	6.7	3.8	5.4	1.5	6.7	17.6	21.5	13.3	1.25	133	1260	657	160	4.76	68.6	0.77	4.46	26	45	29	CL	62'4"-63'1"

Appendix Table 1. (continued)

Sample Number	Sat. pH	Elec. Cond.	ESP	% O.M.	CEC	meq/l Saturated Ext. Ca	Mg	Na	K	NH_4OAC Ext. ppm K	Ca	Mg	Na	DTPA Ext. ppm Zn	Fe	Cu	Mn	Particle Size % S	% Si	% C	Class	Depth
B. H. 6																						
12	6.3	6.5	9.7	2.3	11.8	28.0	36.7	33.4	1.98	118	998	599	276	9.96	38.4	3.20	0.28	15	44	41	SiC	72'2"-72'8"
13	4.2	6.4	6.9	2.6	10.7	26.2	41.8	23.5	1.63	121	1440	843	384	9.16	165.0	3.36	0.56	17	41	42	SiC	73'8"-74'2"
14	4.2	7.0	7.4	3.6	19.7	25.2	50.9	26.5	1.68	299	2270	1840	619	9.38	390.0	4.12	1.00	30	12	58	C	77'-77'6"
15	3.8	8.6	8.6	4.4	18.4	27.4	63.5	34.4	1.71	261	2170	1610	617	30.0	210.0	6.26	0.86	27	15	58	C	81'6"-81'11"
16	5.9	6.4	10.7	0.8	16.7	26.6	29.3	34.8	1.58	290	2030	1140	631	14.2	42.6	3.56	0.50	22	30	48	C	82'3"-82'9"
17	7.1	2.1	7.4	0.7	2.4	5.2	7.2	10.8	0.79	29	1670	190	107	2.34	38.4	1.74	5.90	60	24	16	SL	92'3"-92'9"
18	7.6	1.1	7.7	0.8	22.4	1.8	2.6	6.6	0.50	59	3380	190	77	3.39	38.9	0.84	5.71	70	18	12	SL	101'5"-102'0"
19	8.4	1.1	10.0	0.6	5.1	1.9	1.7	8.2	0.41	124	3850	373	175	4.26	17.2	0.76	3.92	23	46	31	CL	103'2"-103'7"
20	7.8	1.4	9.9	2.2	13.7	2.8	2.5	9.7	0.42	207	1790	766	326	5.08	21.0	2.26	2.32	13	33	54	C	108'9"-109'4"
21	7.7	2.0	16.9	1.7	2.3	2.5	1.8	16.9	0.38	40	267	124	231	1.13	9.2	1.61	0.22	42	42	16	L	122'7"-123'11"
22	8.1	2.9	23.1	0.6	15.1	2.7	2.1	26.2	0.38	281	1600	796	1390	21.8	19.4	15.70	0.40	14	20	66	C	130'11"-131'5"
23	8.1	2.5	21.6	0.4	9.6	2.4	1.6	22.1	0.38	164	962	462	909	2.72	17.4	2.04	0.26	13	47	40	SiCL	132'4"-132'10"
24	8.3	3.3	25.2	0.4	12.3	2.6	2.1	29.3	0.56	277	1340	631	1260	1.05	22.8	3.74	0.26	9	42	40	C	133'4"-133'10"
25	8.4	1.7	21.7	0.7	13.2	1.1	0.8	15.2	0.10	231	1320	416	1410	0.18	32.6	3.02	0.50	40	31	29	CL	142'3"-142'10"
27	8.8	1.5	23.2	0.6	14.3	0.9	0.6	14.8	0.21	282	1480	313	2260	1.38	32.8	4.04	1.05	7	39	54	C	151'3"-151'7"
28	8.7	1.7	18.7	0.5	0.8	1.5	0.9	14.3	0.27	18	484	95	119	3.66	79.6	0.48	4.68	79	13	8	LS	155'-155'3"
29	8.8	1.5	24.5	0.7	16.8	0.8	0.5	15.0	0.13	236	1470	209	3090	2.18	33.4	3.80	1.02	22	29	49	C	159'10"-160'6"
30	8.8	1.3	22.1	0.5	9.8	0.8	0.6	13.2	0.16	173	816	107	1990	0.17	29.0	0.99	0.60	40	37	23	L	162'4"-162'10"
31	8.5	3.6	40.0	0.4	4.9	1.1	0.6	37.4	0.38	109	3450	116	930	1.67	39.8	0.69	2.90	46	34	20	L	172'3"-172'9"
32	8.4	2.0	5.4	0.3	0.5	10.2	6.1	8.6	0.42	10	1470	82	87	1.13	25.8	0.46	3.18	82	14	4	LS	183'3"-183'9"
35	8.6	2.2	24.9	3.2	15.4	1.6	0.8	20.9	0.23	251	983	121	2690	0.64	35.2	2.98	0.65	37	16	47	C	206'10"-107'5"
36	8.7	1.7	22.9	2.0	13.6	1.2	0.8	16.9	0.14	216	843	110	2390	4.26	23.8	0.93	0.49	22	36	42	C	212'2"-212'8"
37	8.7	1.6	22.6	0.5	12.4	1.0	0.6	14.8	0.19	224	861	108	2220	2.66	22.6	1.95	0.66	25	41	34	CL	221'6"-221'8"
39	8.8	1.8	22.8	1.9	11.9	1.4	0.8	17.4	0.14	196	745	79	2310	0.78	15.5	1.59	0.72	20	48	32	SiCL	230'6"-230'11"
40	8.7	1.8	23.9	0.7	6.4	1.2	0.7	17.5	0.26	199	3990	126	1690	0.94	28.2	1.75	8.00	9	57	34	SiCL	232'4"-232'10"
41	8.4	6.2	46.1	1.4	23.2	2.8	1.1	68.6	0.58	404	2100	234	4230	8.72	31.0	2.13	1.31	32	15	53	C	241'10"-242'4"
43	9.0	1.2	23.9	0.5	29.1	0.5	0.4	12.2	0.09	190	1830	105	3690	2.76	22.0	0.60	0.74	18	48	34	SiCL	246'4"-246'8"
45	8.6	2.0	32.4	2.4	17.3	0.8	0.5	22.2	0.26	288	4300	117	2990	4.26	35.4	1.17	3.98	16	49	35	SiCL	252'3"-252'9"
46	8.9	1.9	26.6	0.5	18.3	1.0	0.7	18.7	0.28	359	2030	181	3220	2.24	42.4	5.88	2.98	16	20	64	C	261'5"-261'9"
47	8.9	2.2	28.9	0.6	17.1	1.3	0.7	23.0	0.22	352	1390	143	2840	2.10	45.2	7.04	2.60	10	29	61	C	262'4"-262'10"
48	8.5	4.1	41.1	6.3	9.1	1.8	0.7	44.7	0.44	179	2630	144	1360	1.84	30.2	1.27	4.20	39	34	27	CL	272'3"-272'9"
49	7.5	8.1	19.5	6.9	9.0	29.5	16.0	65.5	1.09	143	2530	339	1030	3.48	93.8	3.08	7.55	50	23	27	SCL	282'3"-282'10"
51	7.7	2.4	2.08	0.4	1.1	11.0	17.8	3.4	0.63	35	314	172	45	1.20	7.16	0.15	0.72	68	23	9	SL	302'3"-302'8"
53	7.9	3.7	1.4	0.7	0.8	24.2	27.0	2.7	0.52	22	421	212	38	3.54	74.2	1.41	6.10	75	15	10	SL	312'3"-312'10"
54	7.7	3.2	1.4	0.5	0.8	24.3	18.3	2.4	0.55	21	515	170	29	10.10	27.0	0.32	3.98	77	16	7	SL	322'3"-322'10"
56	7.8	4.5	2.08	1.7	3.9	28.4	30.3	5.0	0.96	78	1054	453	62	10.30	21.2	1.11	10.50	52	28	20	SCL	332'4"-333'
57	7.9	3.8	1.25	0.6	1.1	29.5	26.2	2.4	0.63	17	3540	150	24	0.57	23.6	0.28	4.46	82	13	5	LS	342'3"-343'11"

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